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Let Our Experience Work For You

Partial Discharge Monitoring Technology

By

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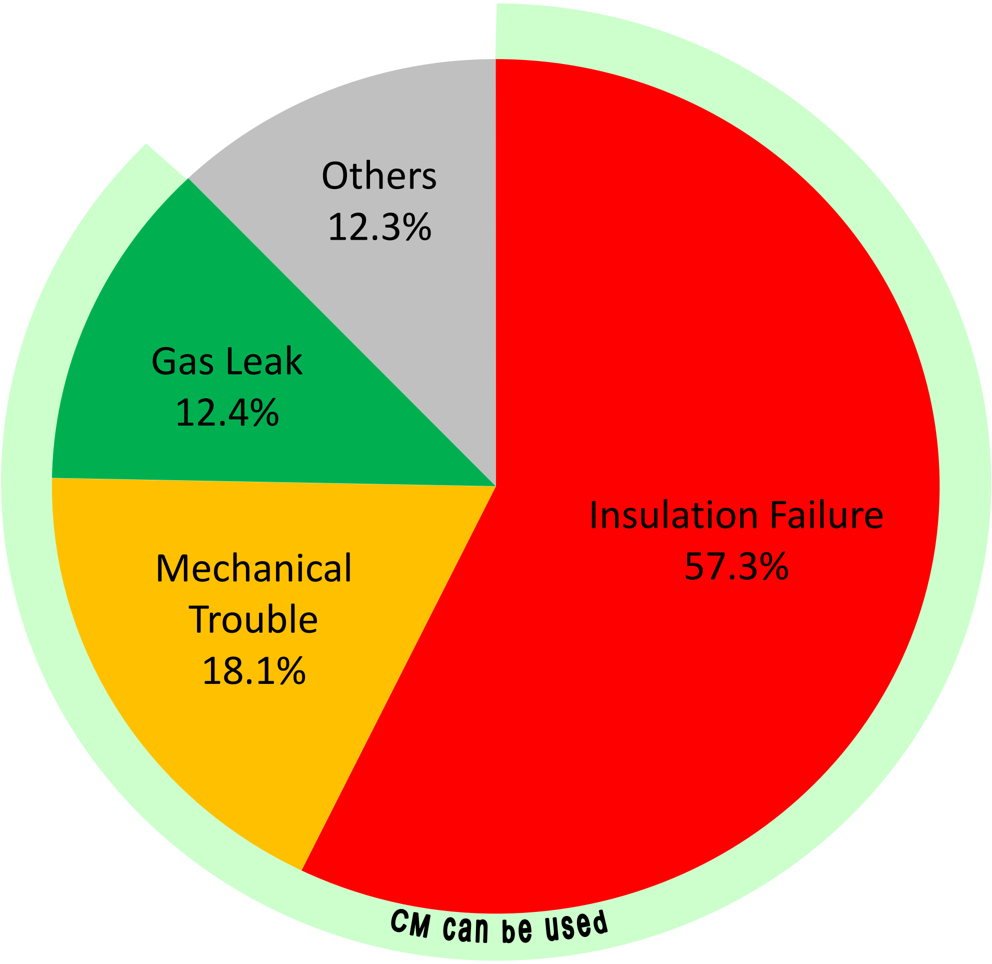
Technical Support Dept.

TechnoMaster Co.

How reliable is GIS?

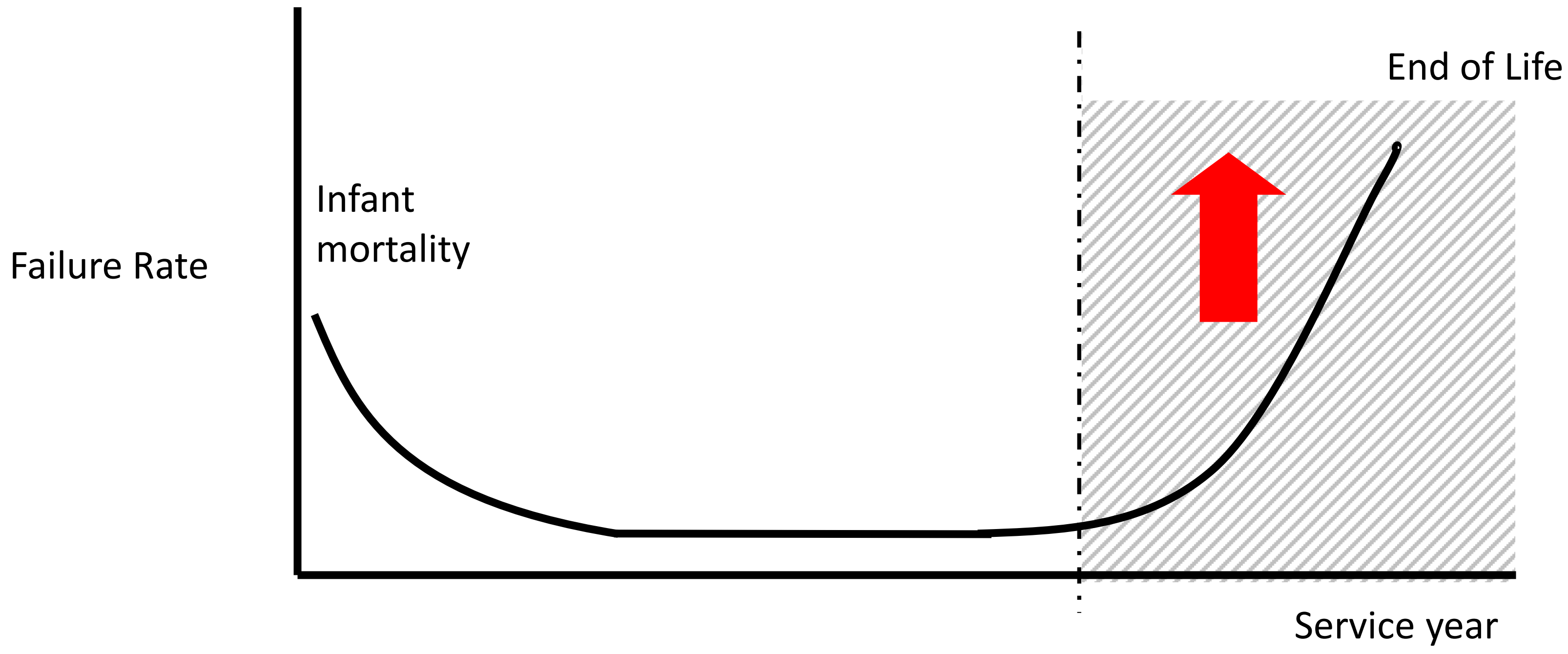
GIS failure statistics (Cigre 1992)



Causes of Major failures

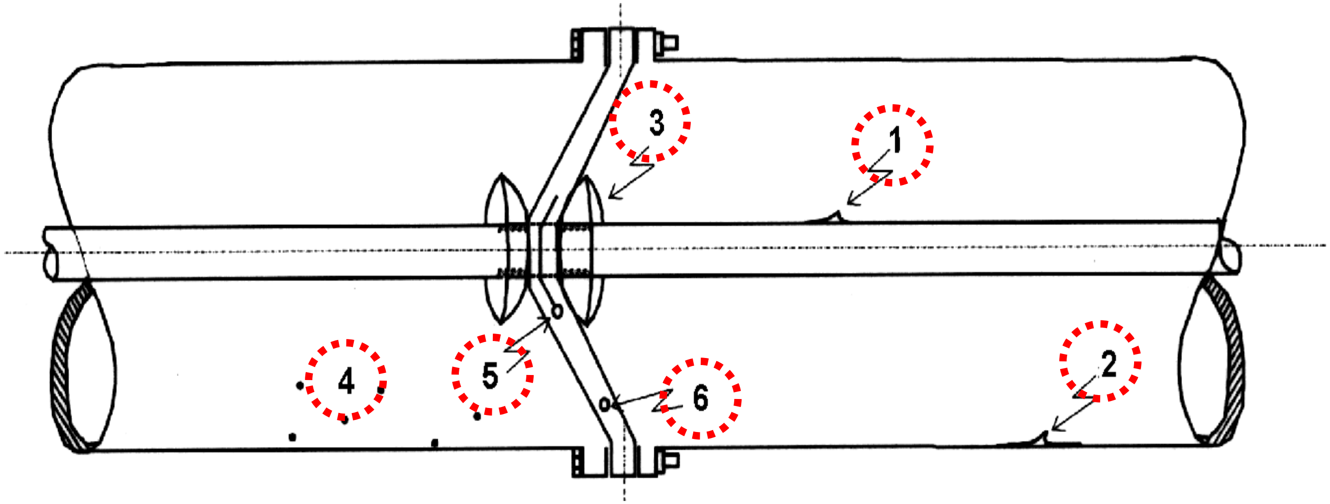
GIS Major Failures

GIS Major Failure Rate increases after 25-years Service



PARTIAL DISCHARGE MONITORING OF GIS USING THE UHF METHOD

Causes of partial discharge in GIS



1- protrusions on conductor (fixed particle)

2- protrusions on enclosure (fixed particle)

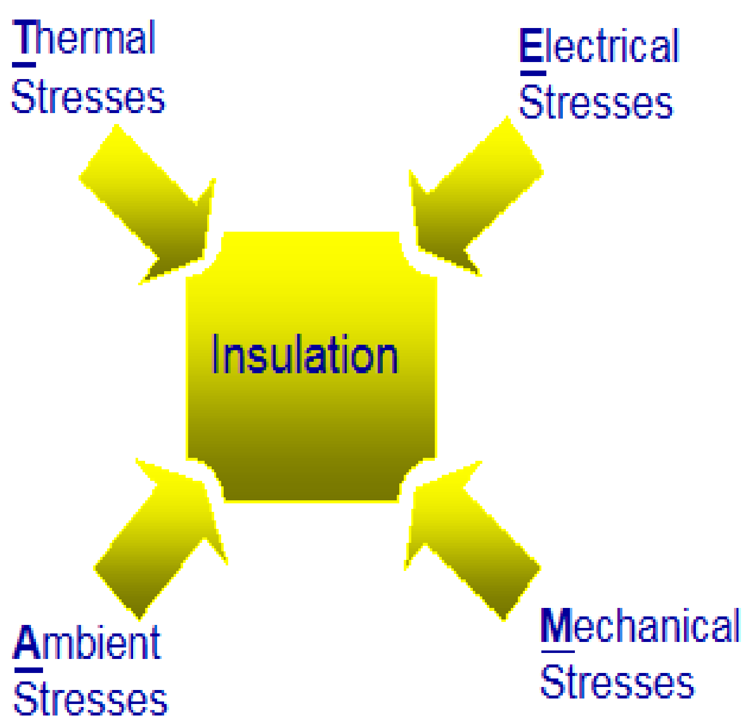
3- floating parts (bad galvanic contact)

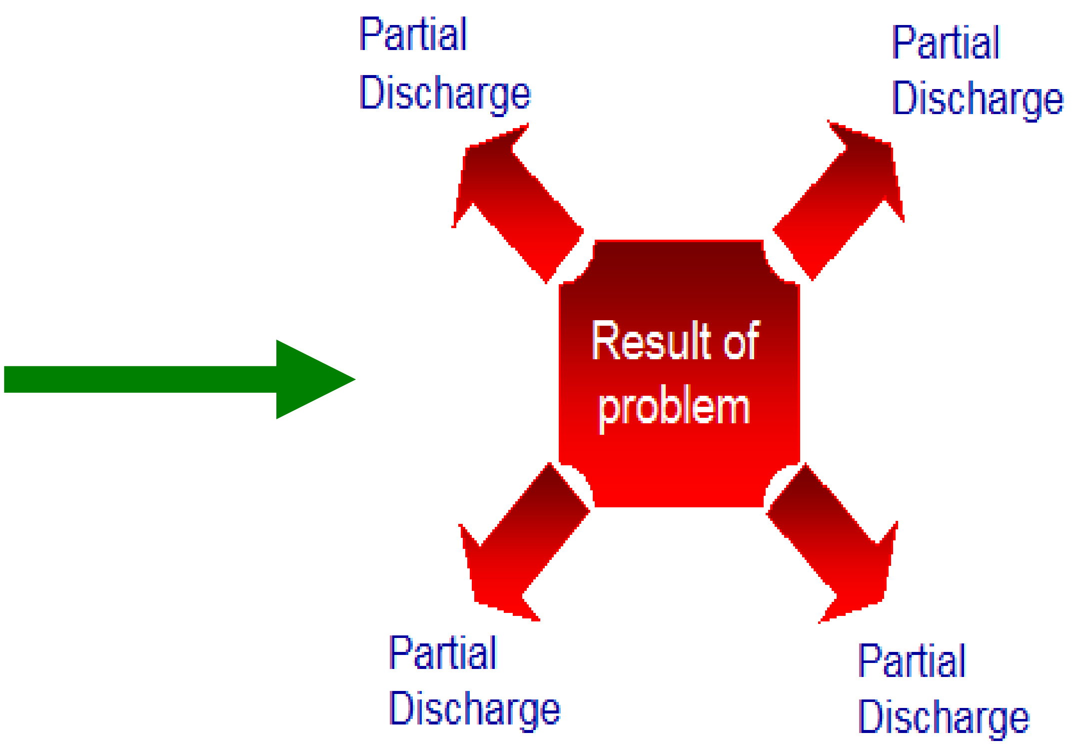
4- free particles on live parts and insulators

5- voids (delamination) between screens and insulation

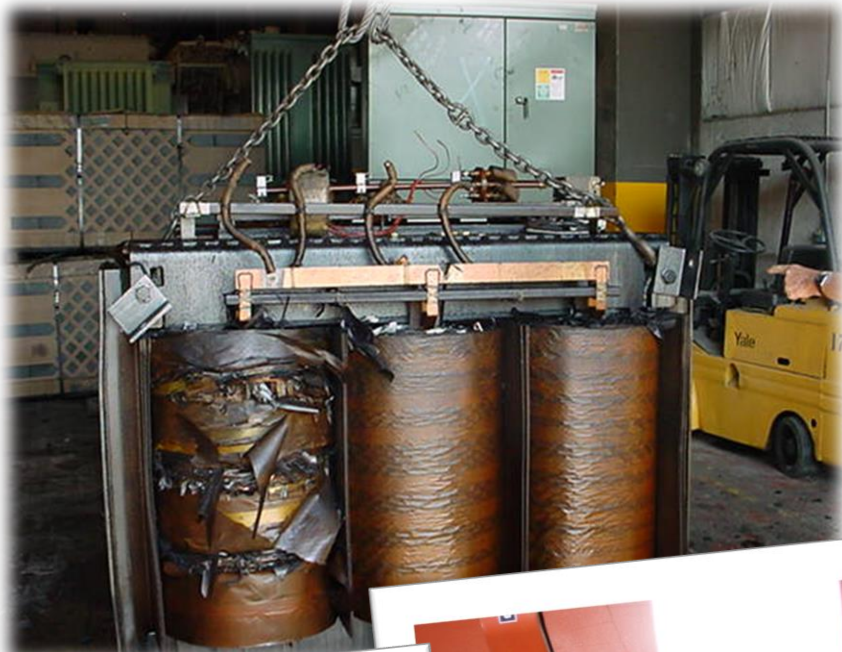
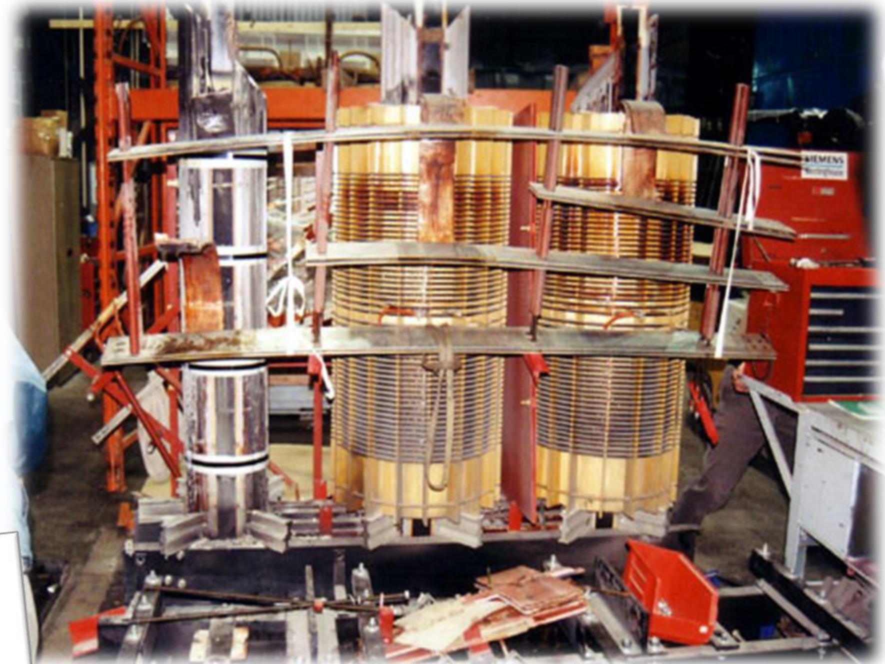
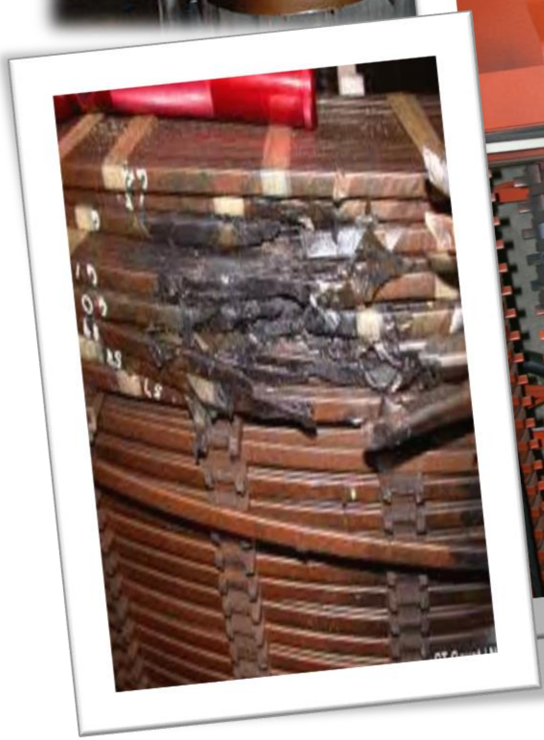
6- voids and treeing in insulation

General sources of Partial Discharge?






Motor Stator Winding Failure


Yale

SIEMENS


The following movie will show us real PD pulses occurs within the insulator

Why Monitor PD?

PD monitoring enables you to do the 3 “**Rights**” of maintenance:

the **Right** maintenance on
the **Right** machines at
the **Right** time

5 Advantages to monitor PD :

1. ***Avoid unnecessary rewinds on older machines by maximizing the operating hours***

****Why rewind if the winding is still in good shape?***

2. ***Extend the Lifetime of Your Winding Insulation***
3. **Extend up-time between outages**
4. ***Reduce Capital Costs***
5. ***Maximize Production Revenue***

More 5 Advantages to monitor PD :

6. *Simple, Safe, and Inexpensive to Test*
7. *Find problems on new machines which may still be under warranty*
8. *Confirm Effectiveness of Repairs*
9. *Non-Destructive Test*
10. *Accomplish all this while the machine remains in operation (On-Line)*

PHYSICS OF PD DETECTION

Partial discharge can be detected by

- Light Detection
- Electrical Detection
- Chemical Detection
- Acoustic Detection
- IEC 60270 Method

Light Detection

Method: high sensitivity photomultiplier near HV parts.

- **most sensitive**
- **radiation in the UV band**
- **strongly absorbed by glass and SF6 - powerful laboratory technique for basic research**
- **not practical for online monitoring of GIS**

Chemical By-products

Method: Chemical reagent tubes or gas analyser.

- immune to electrical interference
- for a steady discharge, diagnostic gas should rise to a level where it can be detected
- small volume lab tests, a 10-15pC discharge can be detected after some tens of hours
- insensitive due to large volumes of gas in GIS
- Shows total integrated equivalent PD over time (similar to DGA)
- although still being studied - some success in smaller GIS gas compartments

Acoustic Emission

Method: Accelerometers or Ultrasonic microphones

- **sensitive, particularly for particles on chamber floor**
- **features of the acoustic signal can infer the shape and movement of a particle**
- **the measurements can be made external to the GIS**
- **commonly used during site acceptance testing, easy to use**
- **accurate location by finger printing along GIS or by time of flight using two sensors**
- **attenuation of signal is high, particularly on barriers so unsuited for detection of void type defects**
- **often used to backup UHF technique or where UHF cannot be applied**
- **not suited to permanent monitoring as too many sensors would be required**

Acoustic Emission - Detection

Pistol for simple location

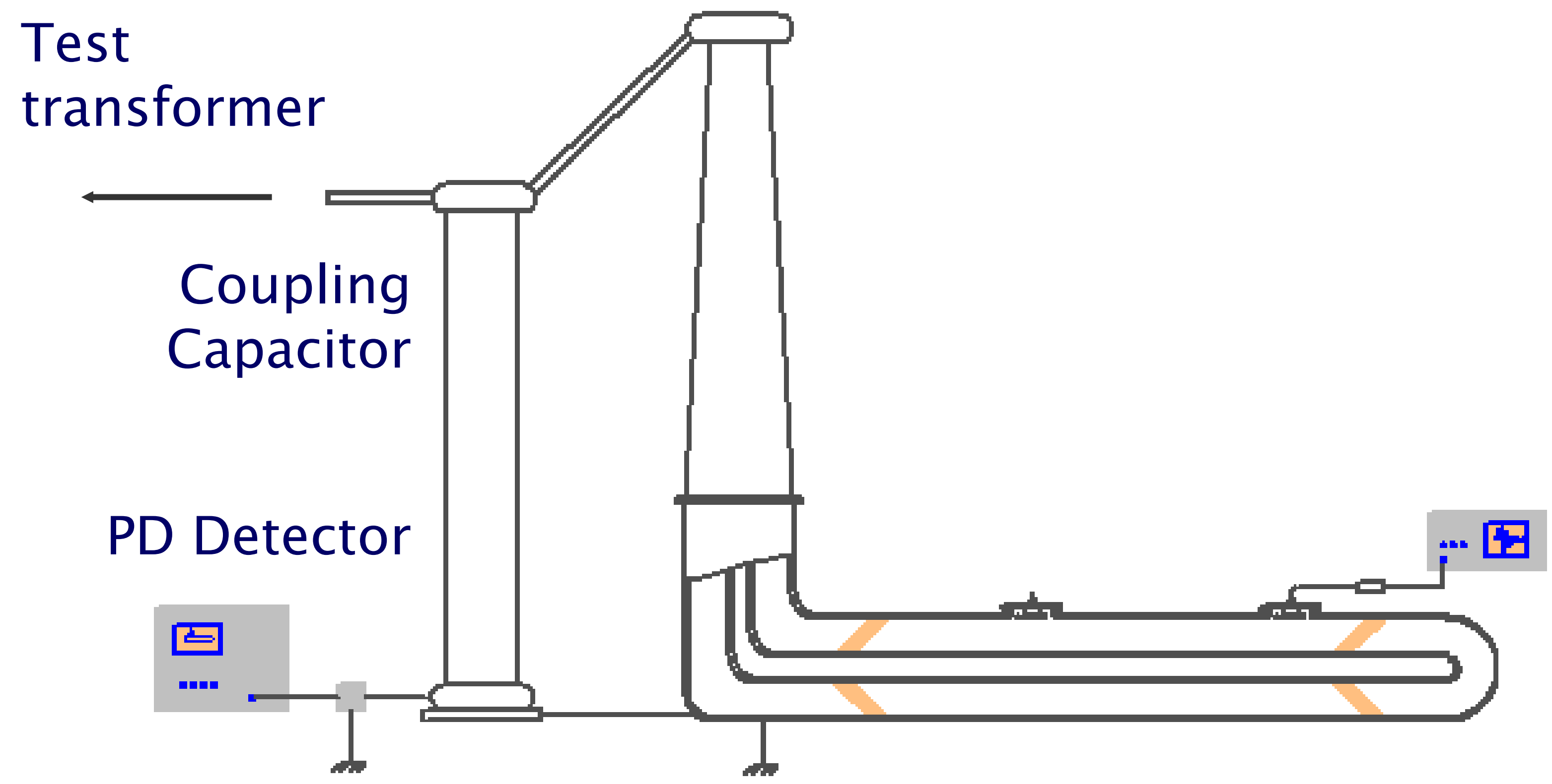
More sophisticated analyser

Conventional IEC270 Method

Method: Coupling capacitor connected to HV part

- **industrial standard**
- **calibrated in PC**
- **for maximum sensitivity, requires completely shielded test arrangement**
- **total capacitance of GIS is high and must be divided into sections for tests**
- **no means to locate discharge**
- **no coupling capacitor on GIS, hence method cannot be used for in-service measurements**

Conventional IEC270 Method



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Electromagnetic Detection

Method: Electric field sensor near HV parts

- **signal is easily detected if noise can be eliminated**
- **for GIS the UHF band offers very high sensitivity to all defect types and good noise rejection**
- **allows relative PD amplitude and pulse activity to be measured**
- **signal contains information on the type of defect producing the PD so defect classification is possible**
- **time of flight measurement using two sensors allows accurate location of discharge**
- **high sensitivity of field sensors means that large sections of GIS can be monitored effectively**
- **preferred method for site testing of EHV GIS**

CIGRE Investigation (1992)

Cigre conducted an evaluation of the various available PD detection methods in 1992:

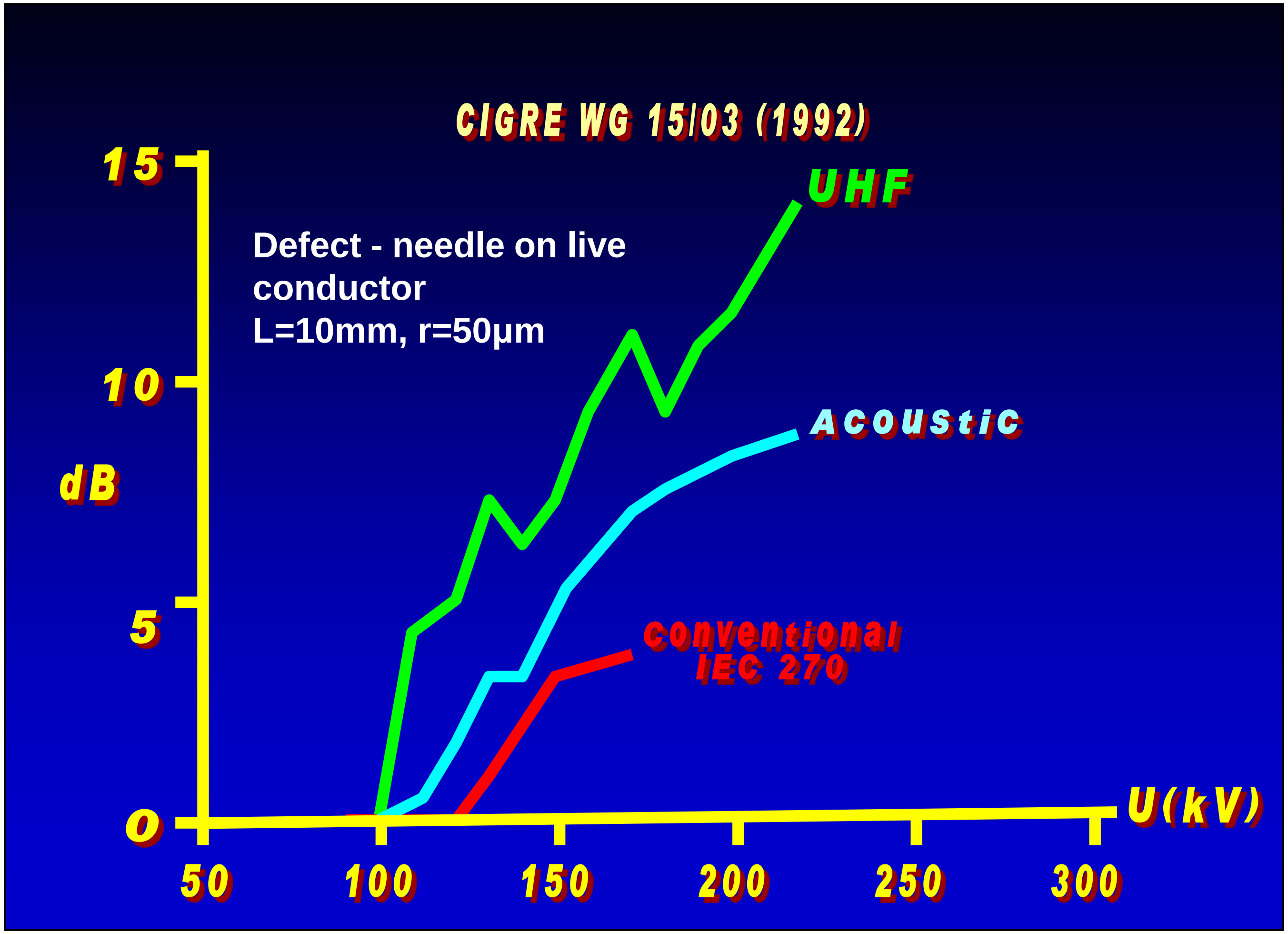
- **conventional PD to IEC270**, with either a standard detector at 1MHz or the PRPD evaluation system at 200MHz
- **UHF** using an internal coupler up to 1500MHz
- external **acoustic** emission sensor at 34kHz
- **chemical** using detector tubes

CIGRE Investigation (1992)

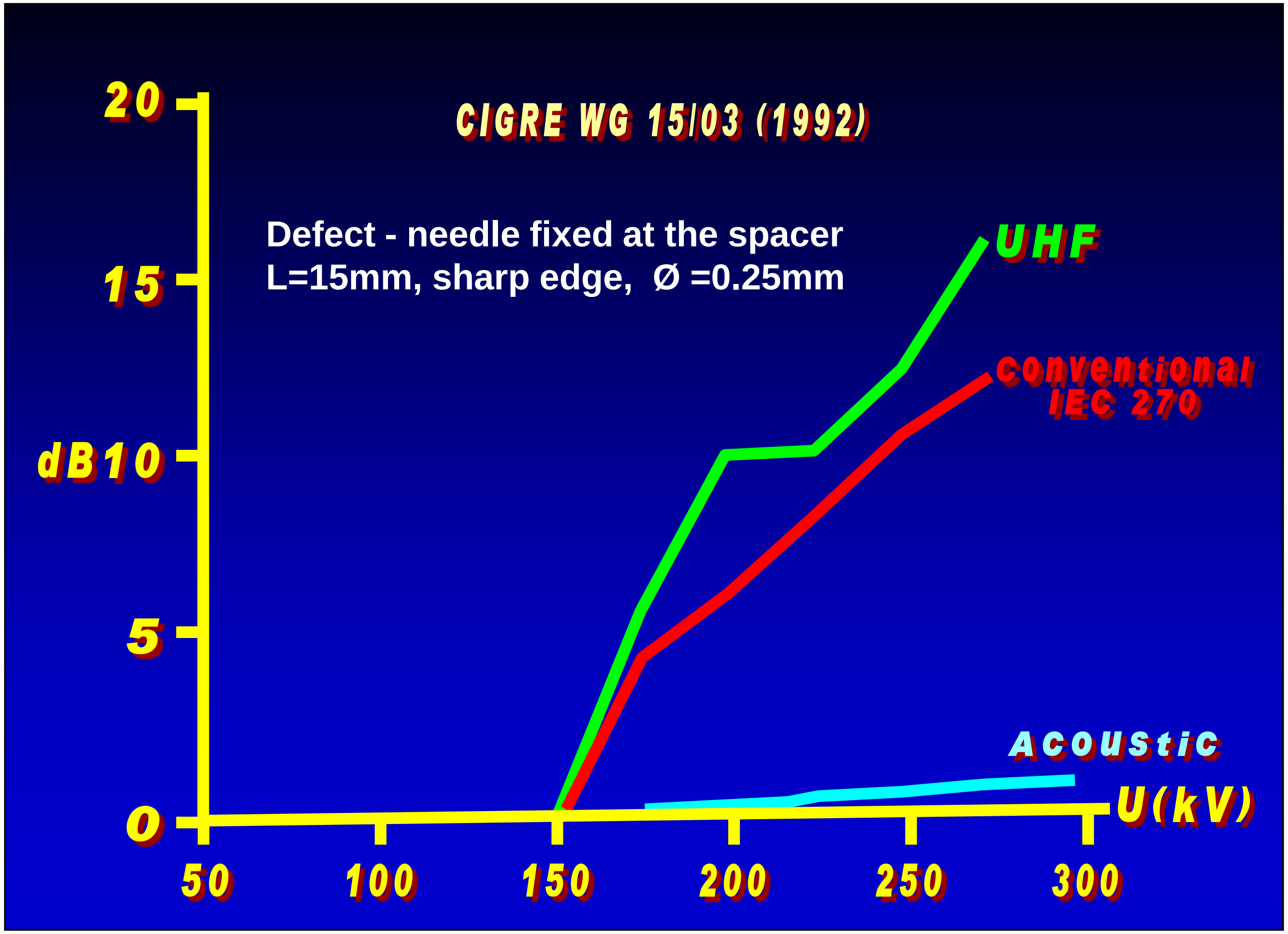
The study concluded:

- acoustic, conventional and UHF techniques show good sensitivity
- acoustic methods are non-intrusive but <u>attenuation of signal</u> across barriers and along chambers is high
- conventional measurements need <u>external coupling capacitor</u> and cannot be used on GIS in-service
- <u>**UHF technique suitable for in-service monitoring**</u>

CIGRE Investigation (1992)



CIGRE Investigation (1992)



Relative Merits:- UHF and Acoustic PD Systems

	UHF-System	Acoustic-System
Main purpose	☺ detection & 😐 localisation of PD sources	☹ detection & ☺ localisation of PD sources
Sensitivity	mobile particles (1-2mm), ☺ ☺ fixed particles (2-5mm) floating components voids in spacers	mobile particles, 😐 fixed particles, floating components ☹ voids in spacers
Measurement time / bay for spot checks	☺ 5-10 minutes, easy and fast	☹ ☹ min. 30 - 90minutes “one has to crawl on GIS”
Suitability for on-line continuous monitoring	☺ ☺ Reliable sensors, noise immune and large sensor spacing	☹ ☹ Unreliable sensors, noise issues and needs many sensors

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Relative Merits:- UHF and Acoustic PD Systems

	UHF-System	**Acoustic-System**
Typical system requirements	😐 ☺ built-in sensors, (or in some cases external spacer sensors)	☺ no built-in sensors required !
Noise reduction	☺ ☺ very effective,	☹ not possible, **additional** noise sources: wind, rain droplets, vibrations, air corona
Data storage	☺ easy and fast on PC	😐 only possible with AIA type instrument
Data analysis during and after measurement	☺ easy and fast, use of PD database for analysing and classifying data	😐 AIA system: possible to some extent

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What Makes a UHF PDM System so Effective:

- can detect all known types of PD in GIS, Transformers or rotating machines
- can record data in a way which allows the analysis of PD using expert system PD pattern interpretation by ANN and feature extraction
- can instantly warn of active PD (no time delay)
- gives indication of the type of PD and therefore helps in determining the risk of failure

What Makes a UHF PDM System so Effective:

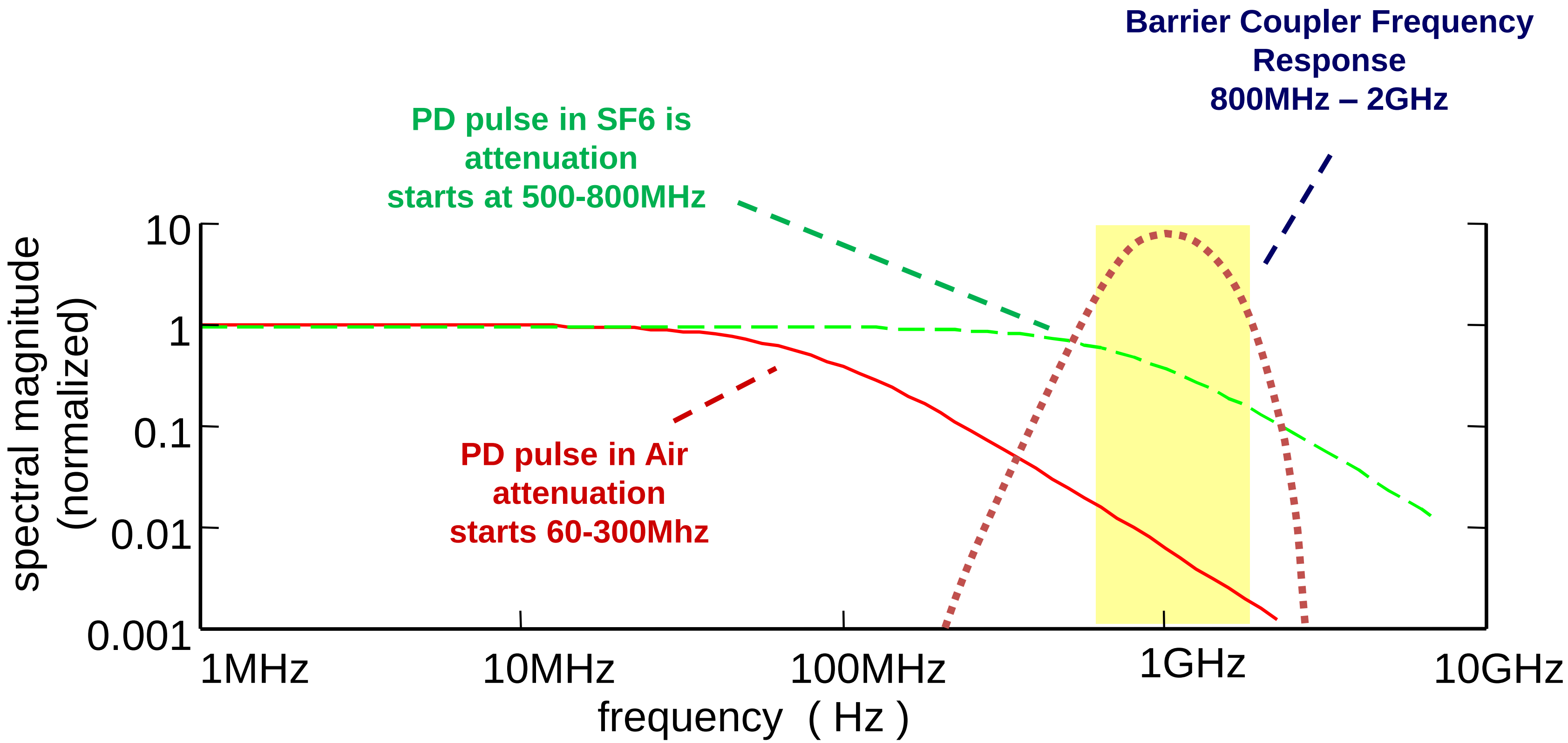
- suitable for periodic and continuous, on-line monitoring in-service
- applicable to all system voltages
- only IEC approved technique for use during HV commissioning tests (of GIS)
- Also suitable for other metal enclosed electrical plant such as, dead tank CBs, cable end boxes and switch-panels

What Makes a UHF PDM System so Effective:

- The UHF method can reject external “air corona” produced noise, as this occurs at lower frequencies (HF and VHF)

- This is because the “fast” PD pulses in SF_6 or Oil produce strong signals at frequencies much higher than normal “air corona”

Physics of PD Attenuation



Best SNR with still
sufficient sensitivity
1GHz±300MHz

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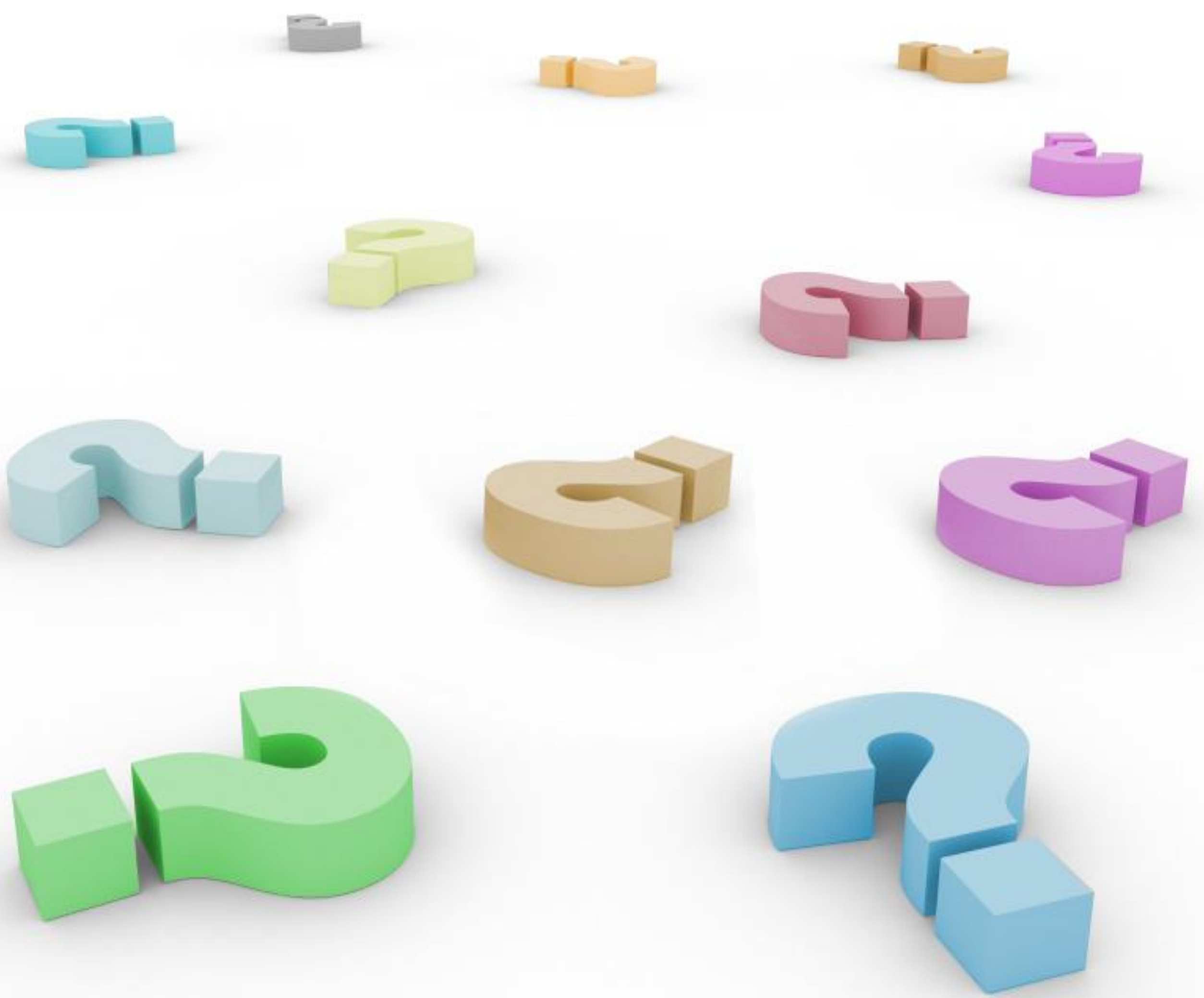
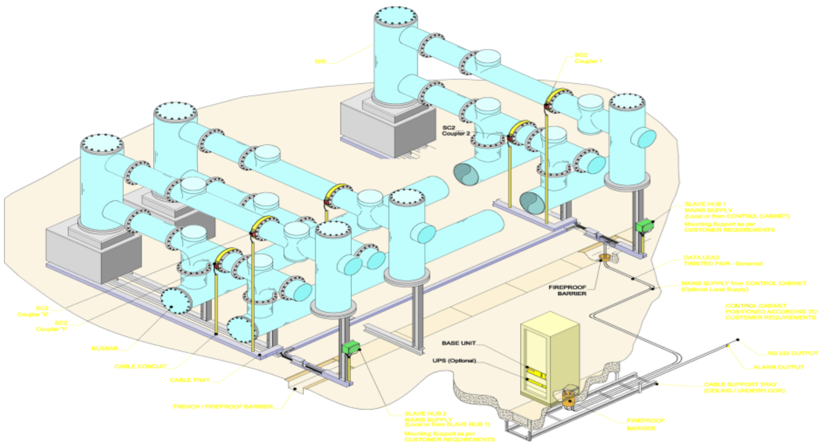
Questions ?



Periodic PD monitoring For Gas Insulated Switchgears GIS (Portable Unit)



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GIS

- Gas Insulated Switchgear
- Gas Insulated Substation
- Compact Gas Insulated Substation
- Gas Insulated Bus
- Gas Insulated Line

SF_6

Sulphur Hexaflouride – the wonder gas

- Very high dielectric strength of 225kV per inch per bar
- Normal GIS operates at 5 bar, 1125kV per inch
- Non toxic, recombines to SF6 after a flashover
- Electro-negative, absorbs free electrons
- Unfortunately one of the worst greenhouse gases

Brazil, 500kV ABB GIS

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Singapore, 230kV Siemens GIS

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Switzerland, 220kV Areva/Alstom GIS

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Korea, 345kV Hyundai GIS

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Singapore, 400kV ABB GIS

Taiwan, 500kV Toshiba GIL

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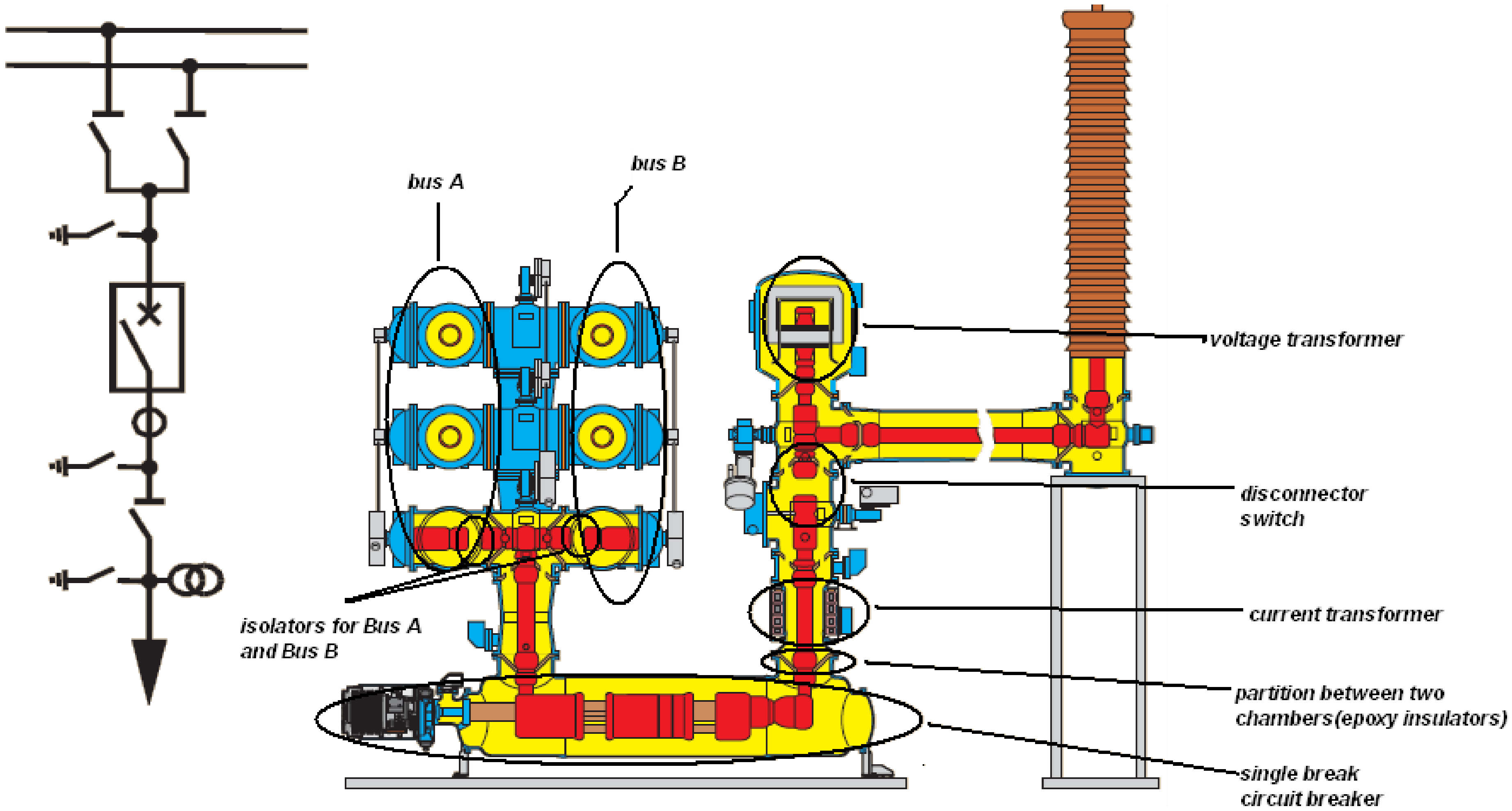
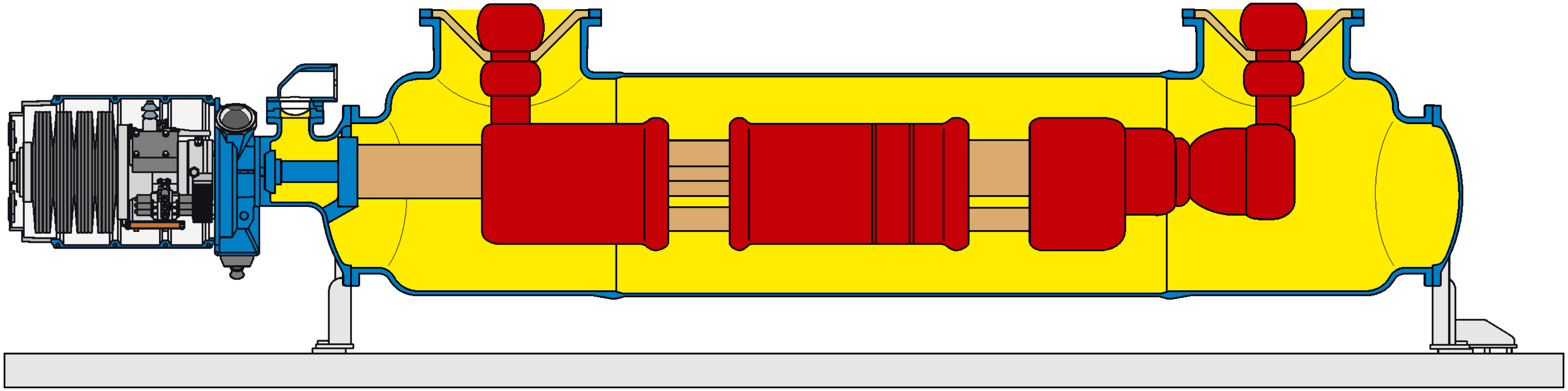
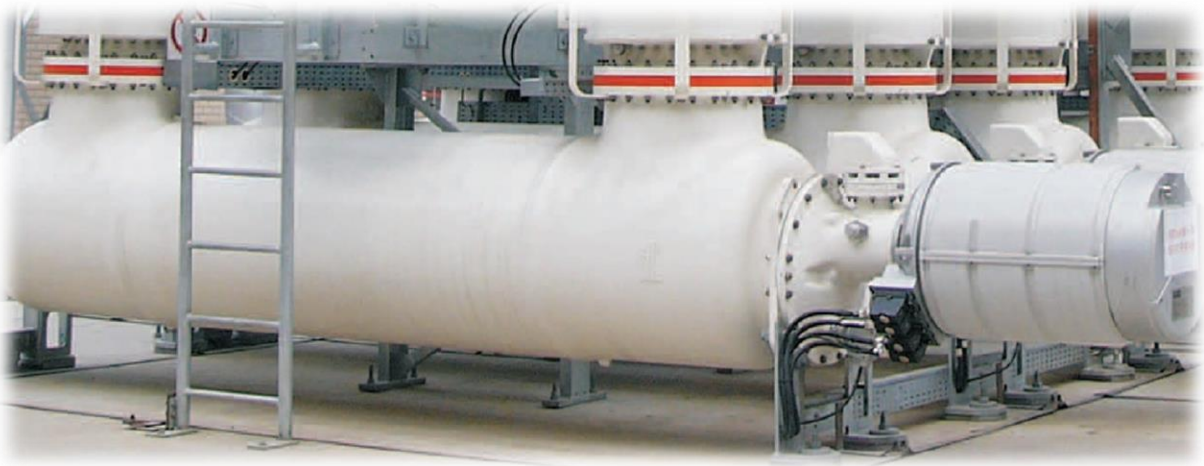
GIS Components



Circuit Breaker





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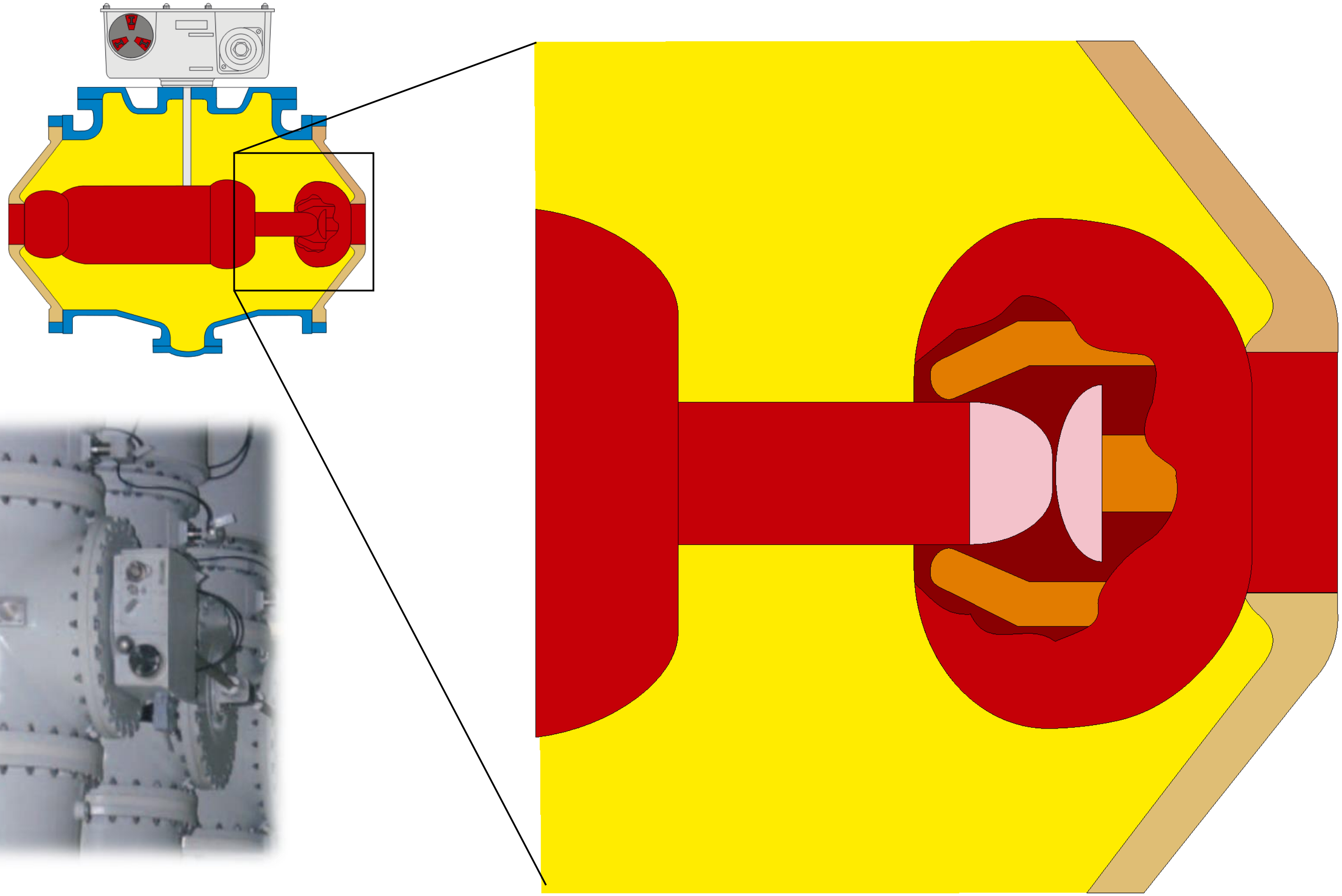
Disconnector



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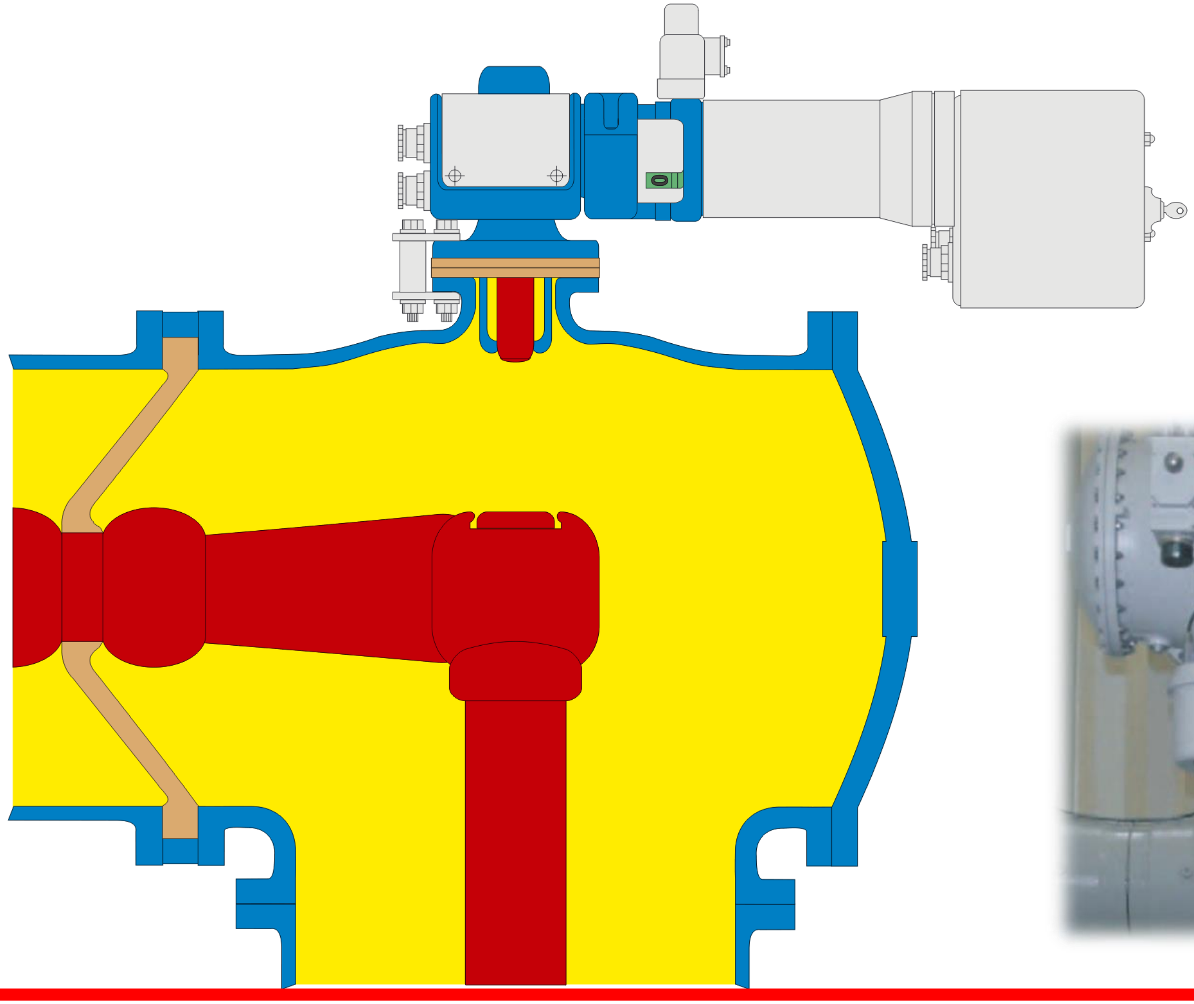
Earth Switch



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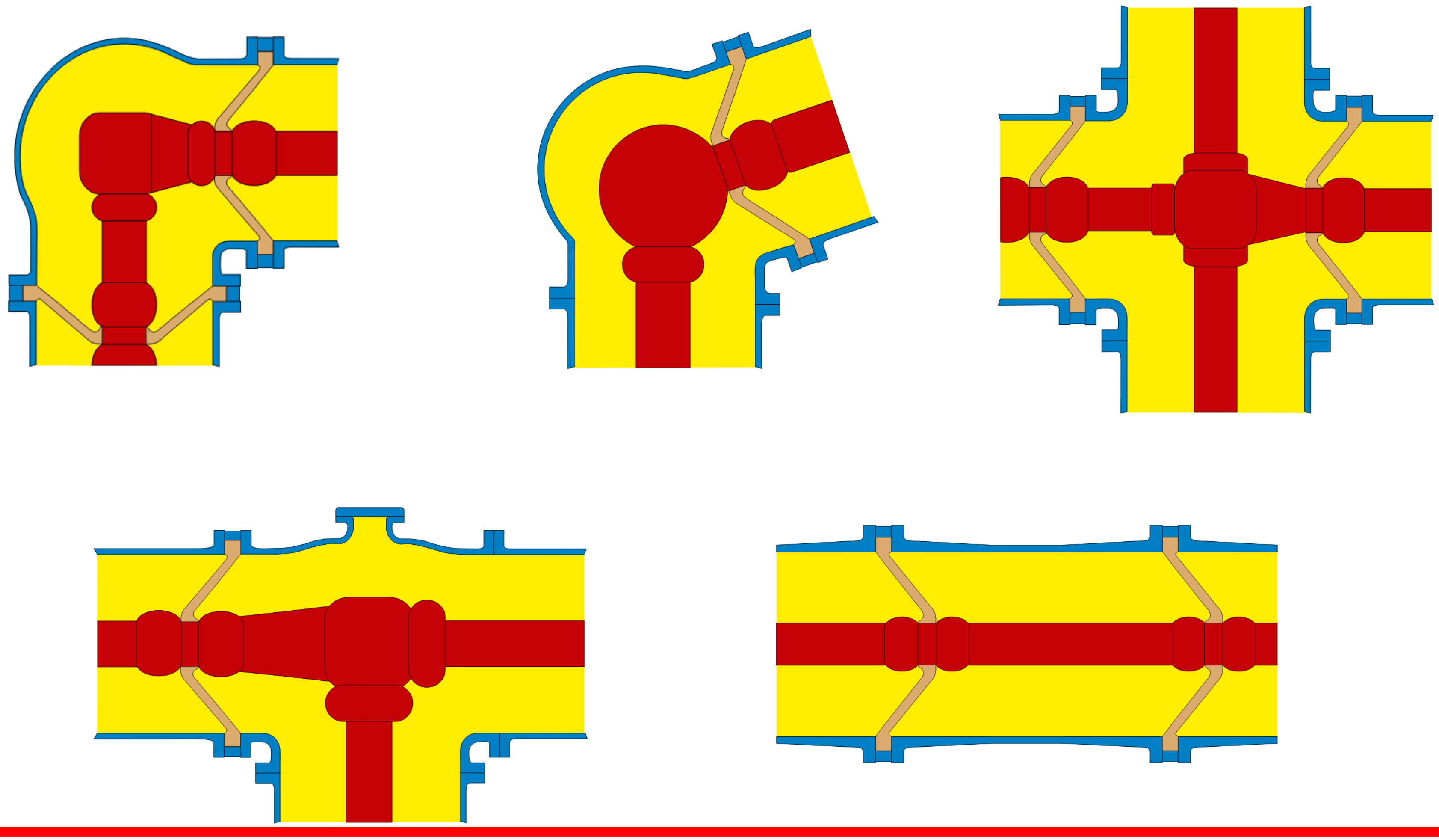
Connecting sections



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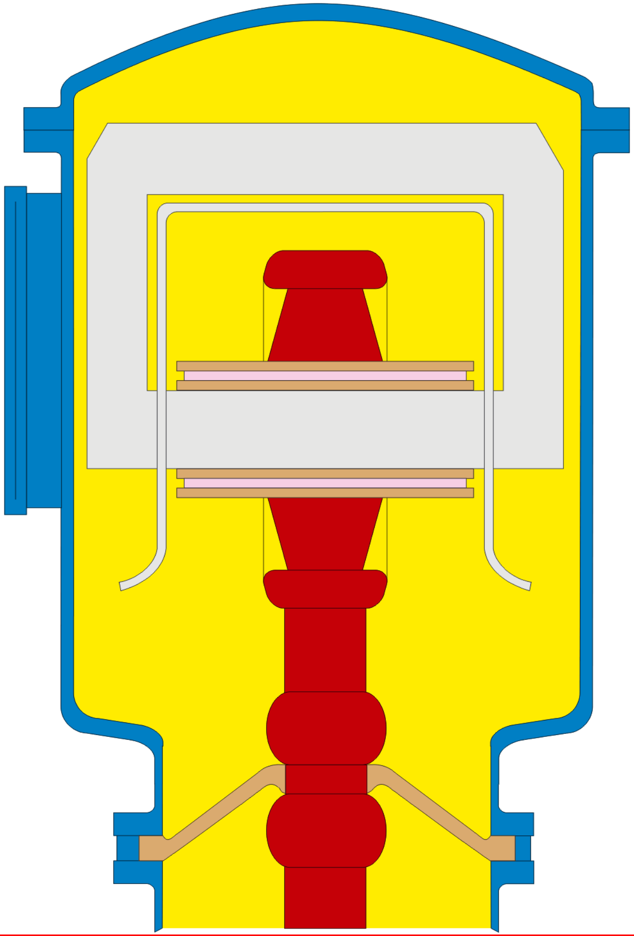
Voltage Transformer



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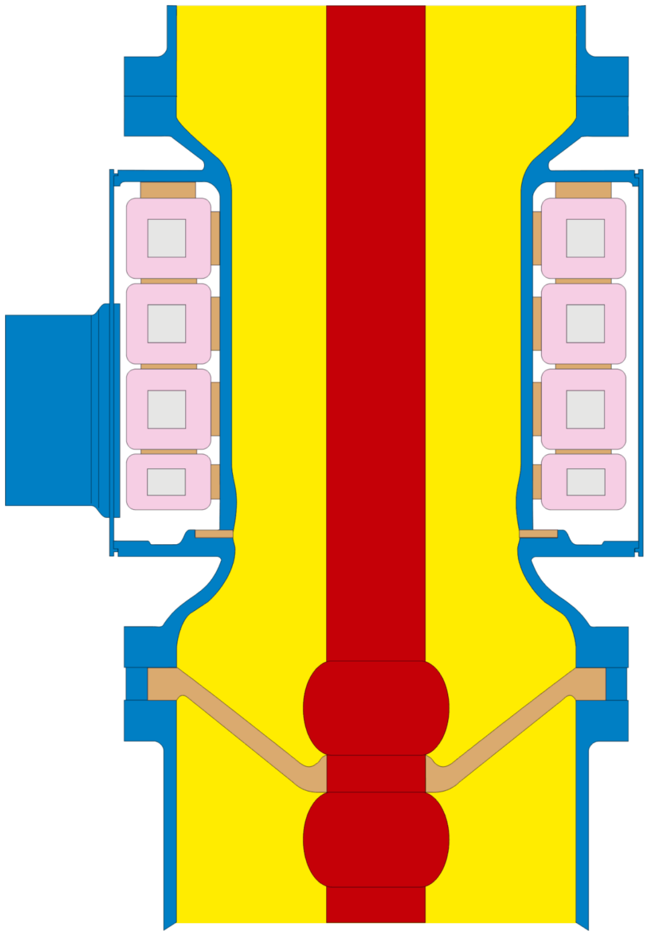
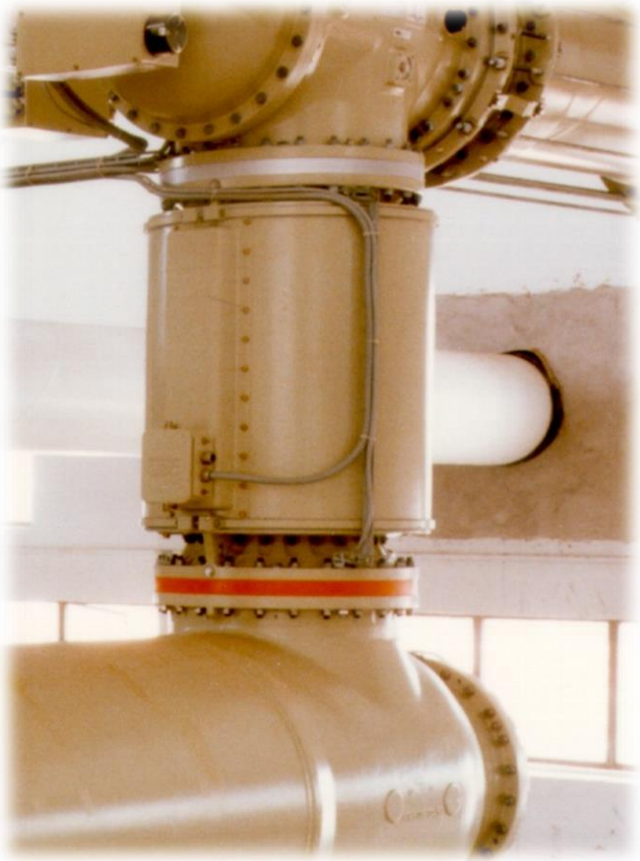
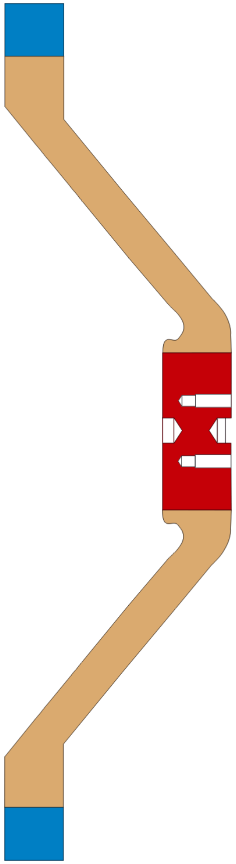
Current Transformer





Barrier support



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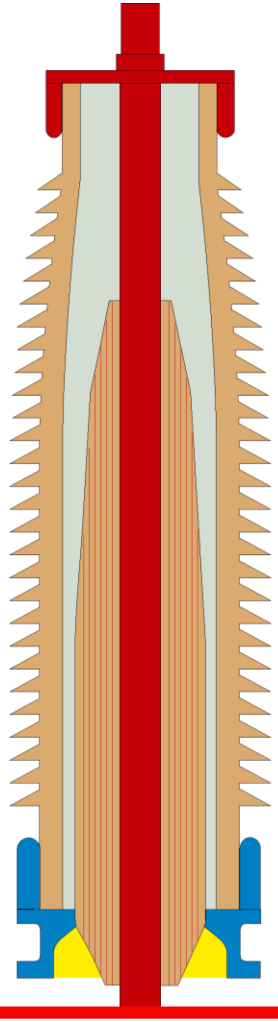
Air Bushing



Air Bushing

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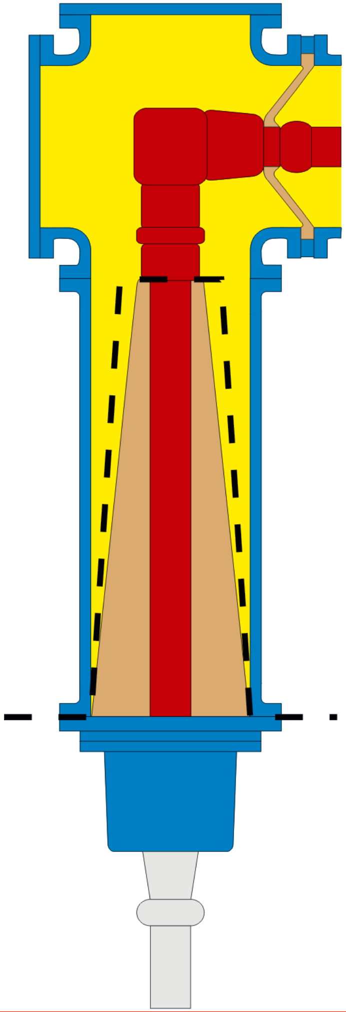
Cable Bushing



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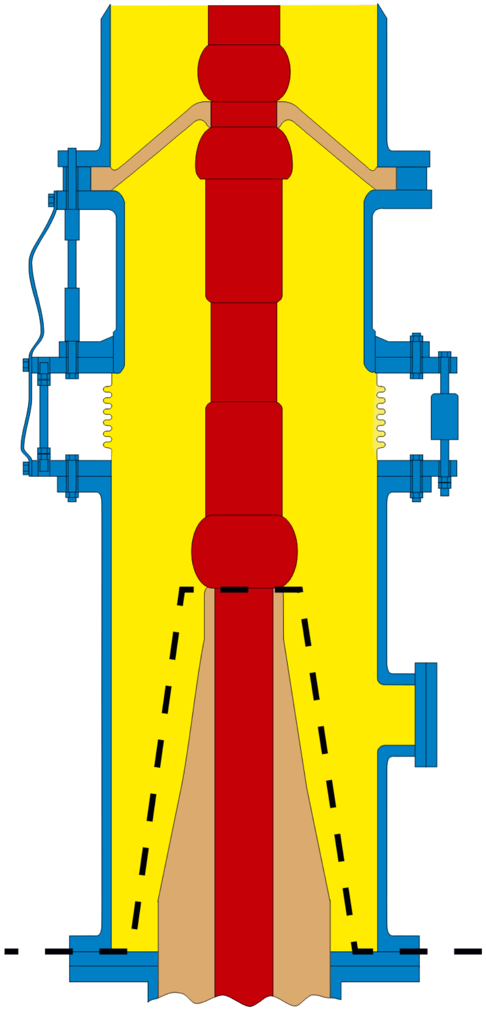
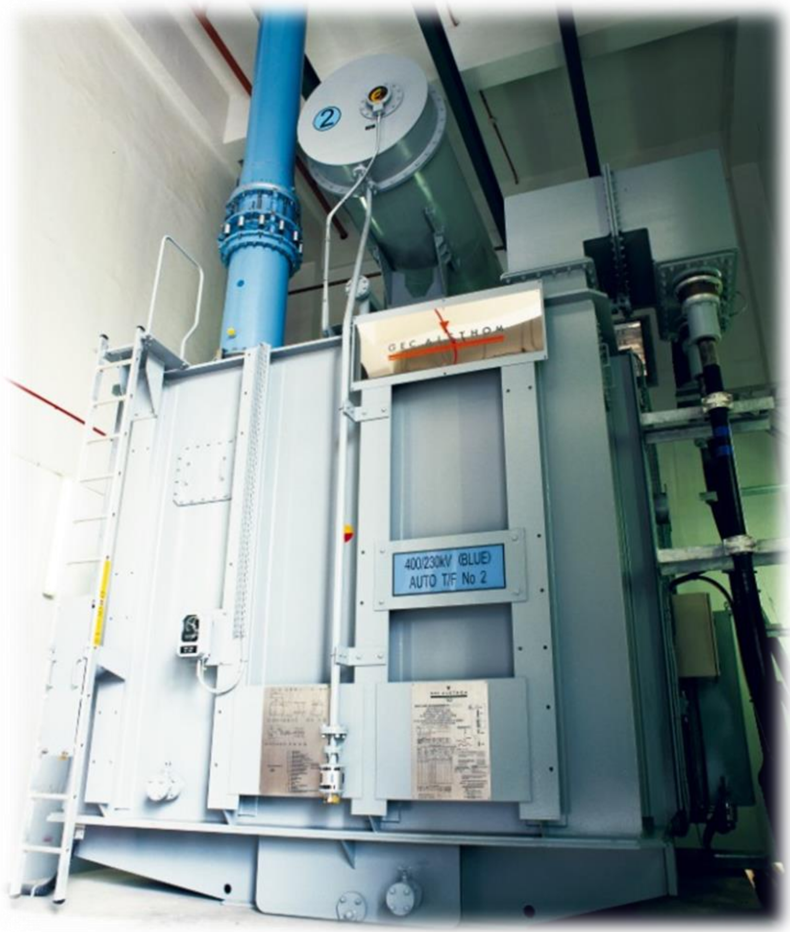
Transformer Bushing





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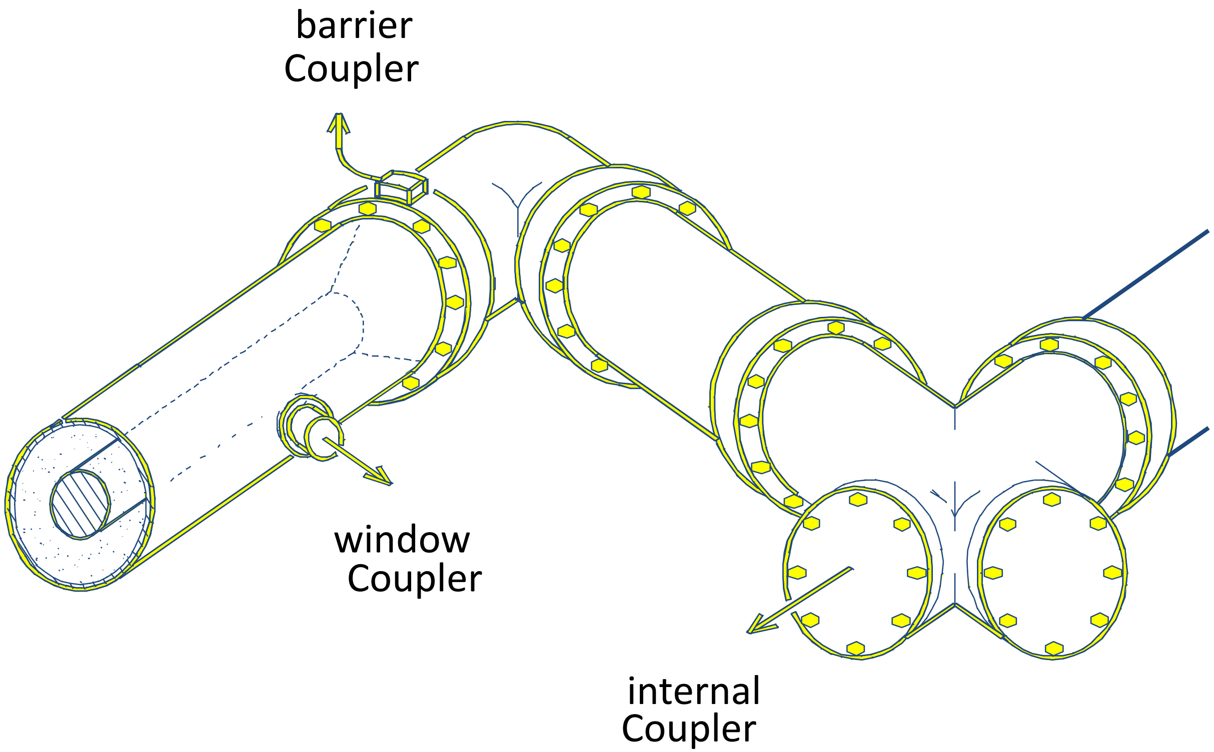
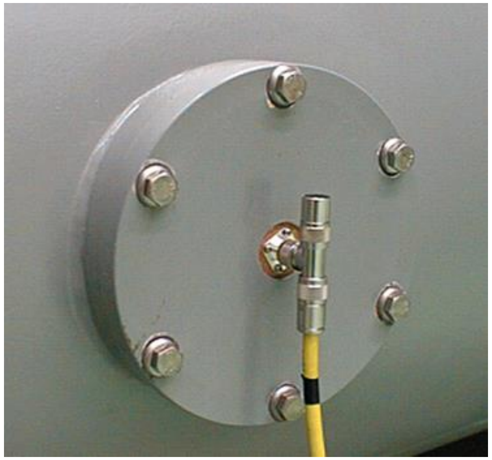
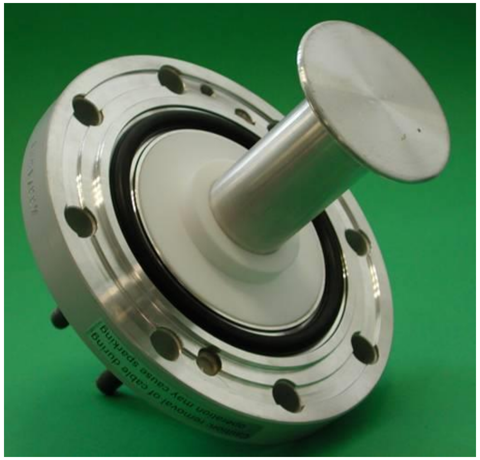
PD Sensors for GIS



Types of UHF coupler for GIS

UHF Internal Couplers





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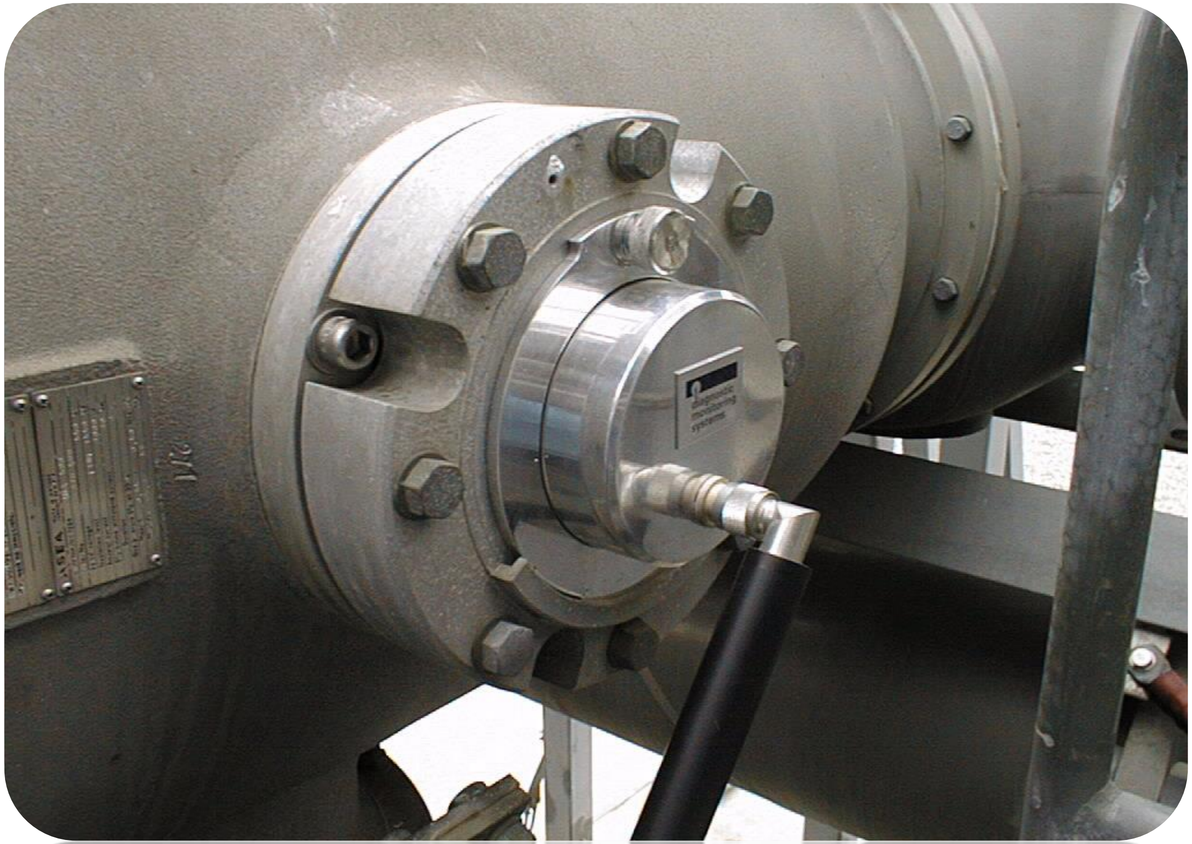
UHF Window Couplers



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UHF Barrier Couplers

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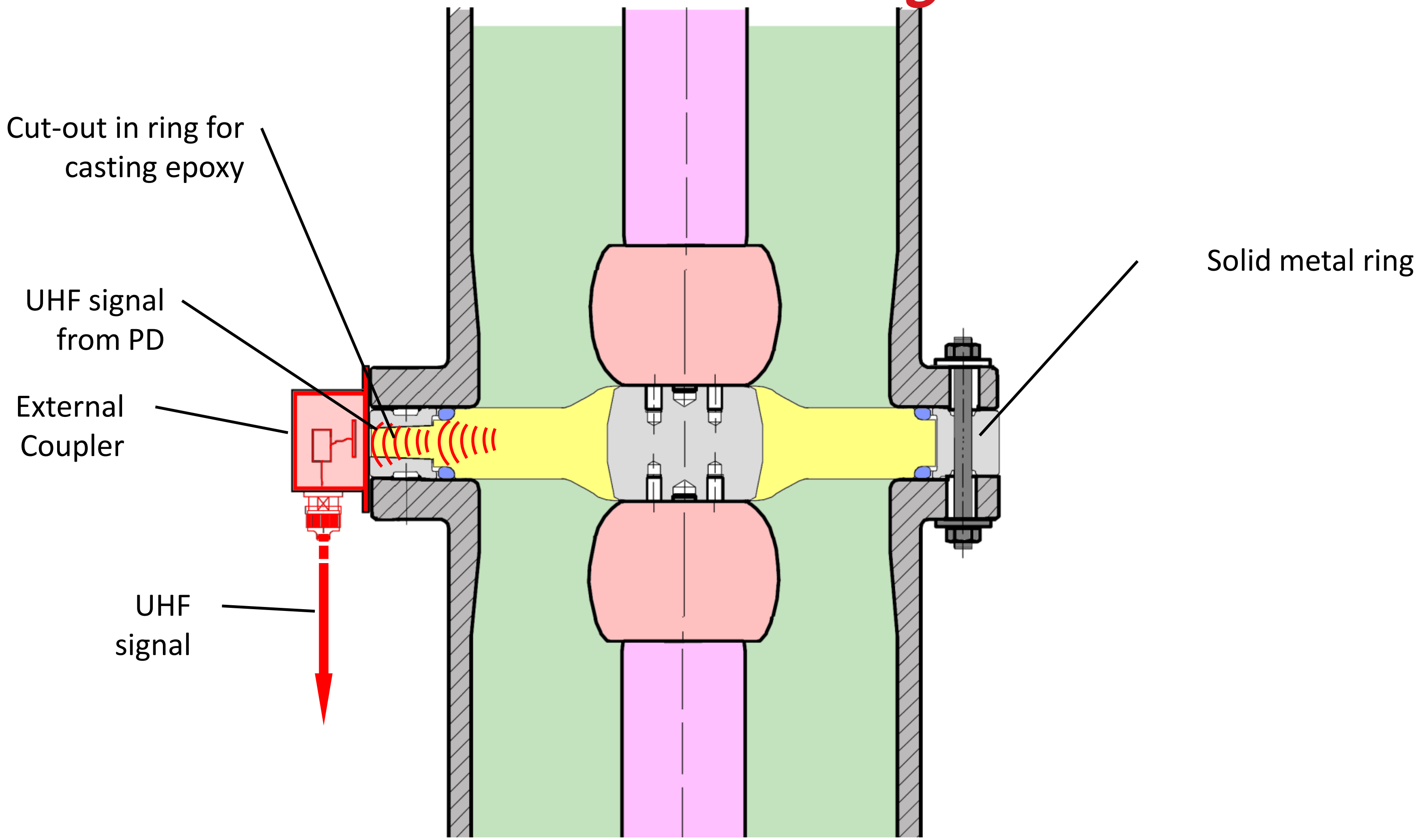
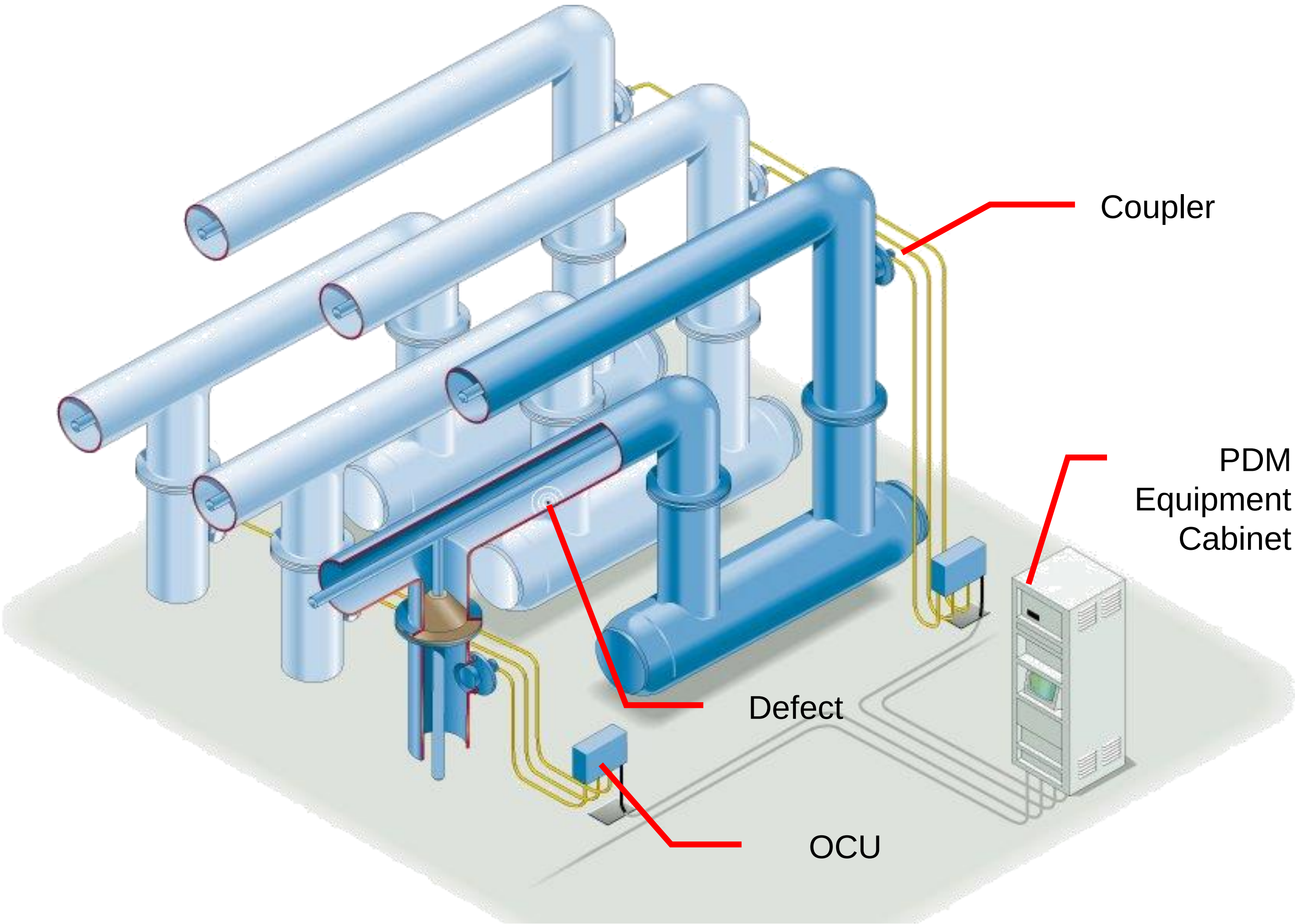
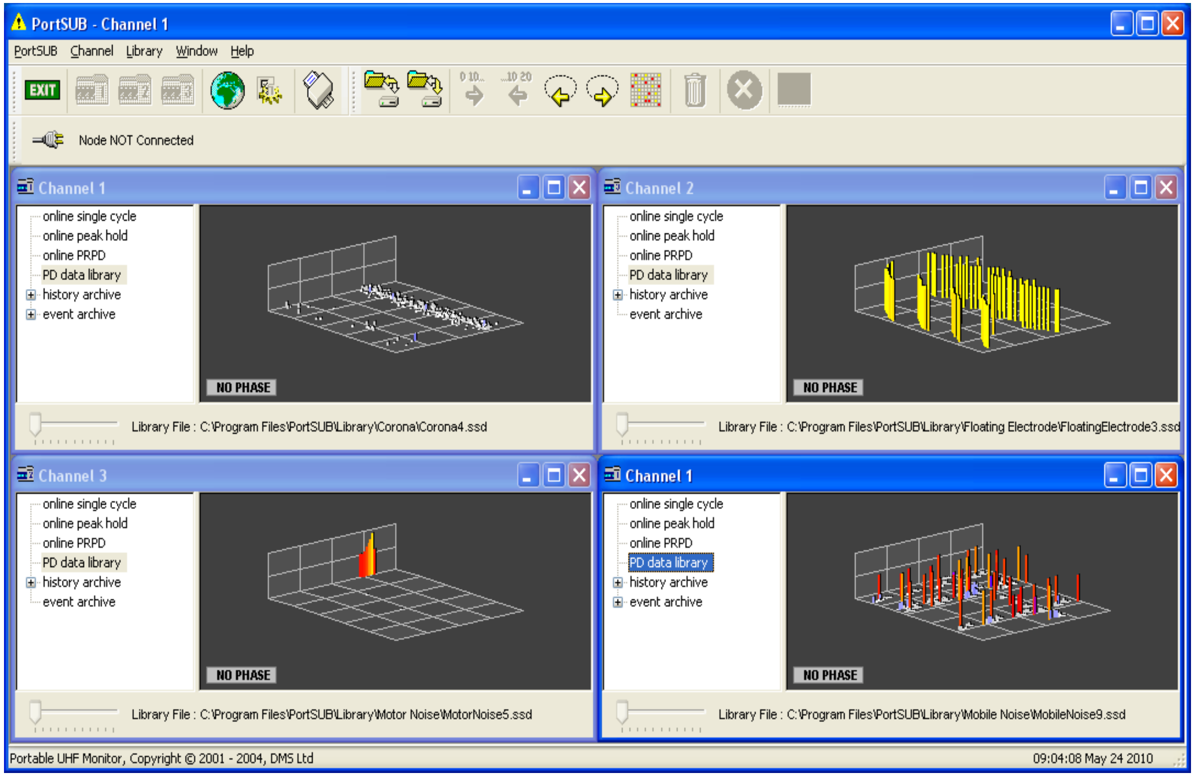
Coupling a UHF signal from a closed GIS spacer with cut-out in outer ring



Radial PDM



Portable PDM
(Partial Discharge Monitoring)
System



Portable PDM System Overview

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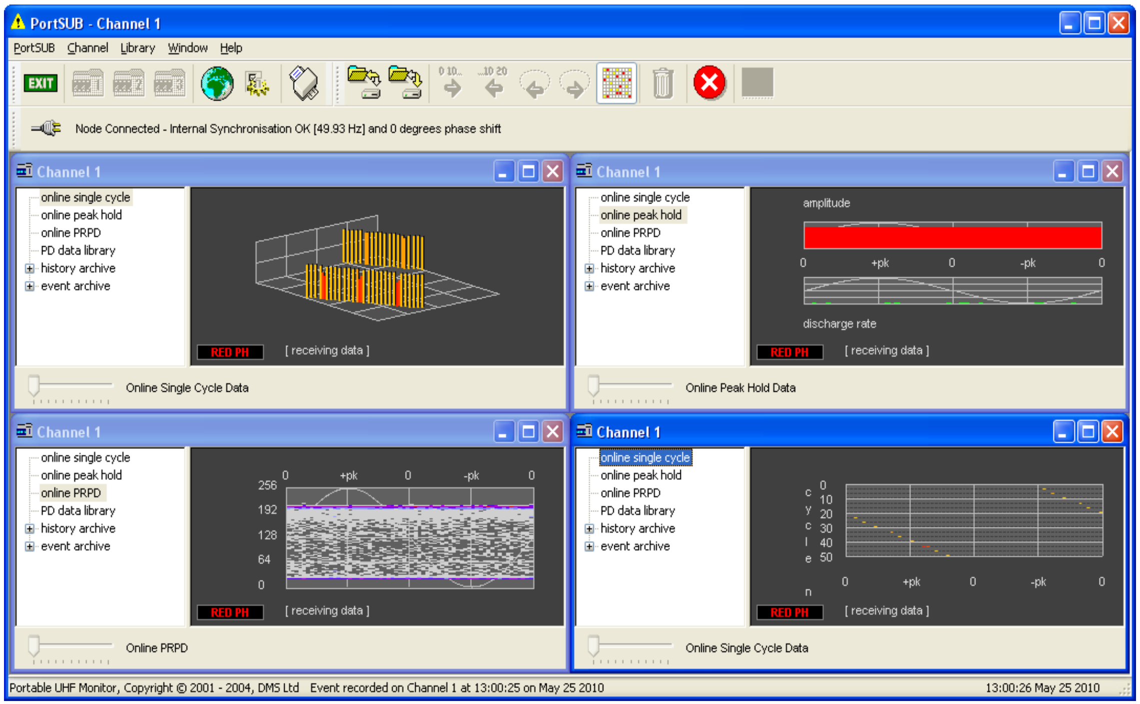
Portable PDM System Overview

- The DMS Portable UHF Monitor **detects and records** the UHF signals generated by partial discharges in a GIS

- The Portable UHF Monitor consists of a base unit and a detachable laptop computer which are fitted into an aluminium travelling case and require only an external mains supply to be ready for use. The Monitor can be left connected and unattended, where it will record and store data from up to three couplers.

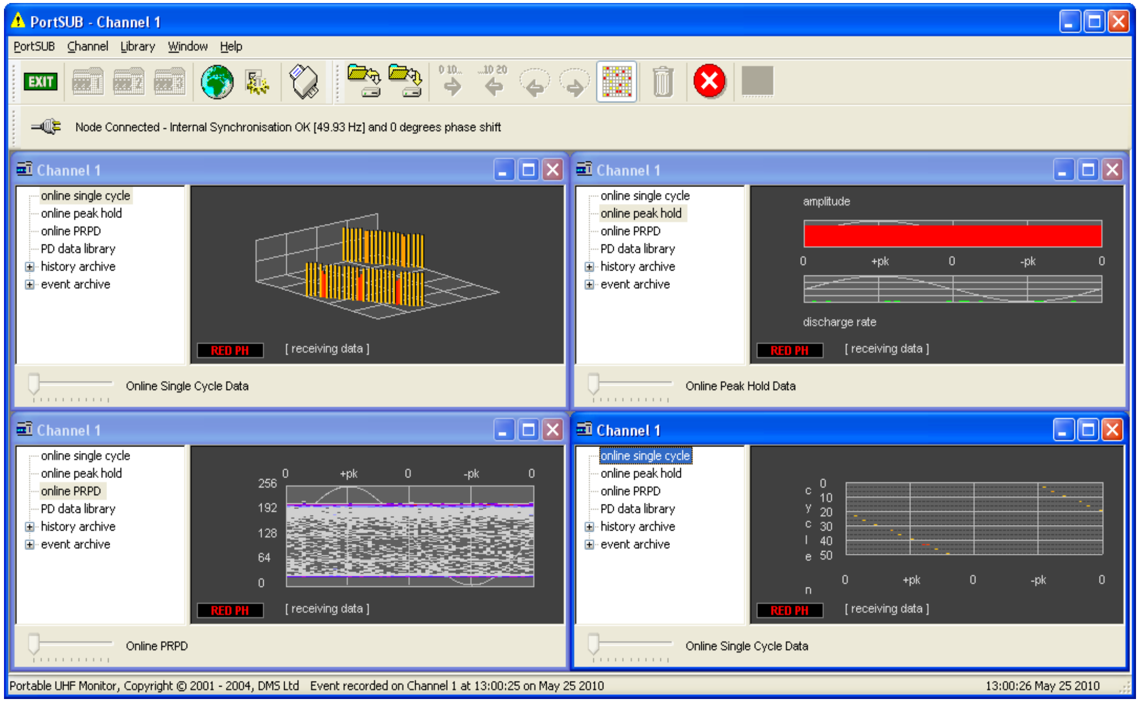
PDM System Overview Software

PortSUB



PDM System Overview Software

PortSUB



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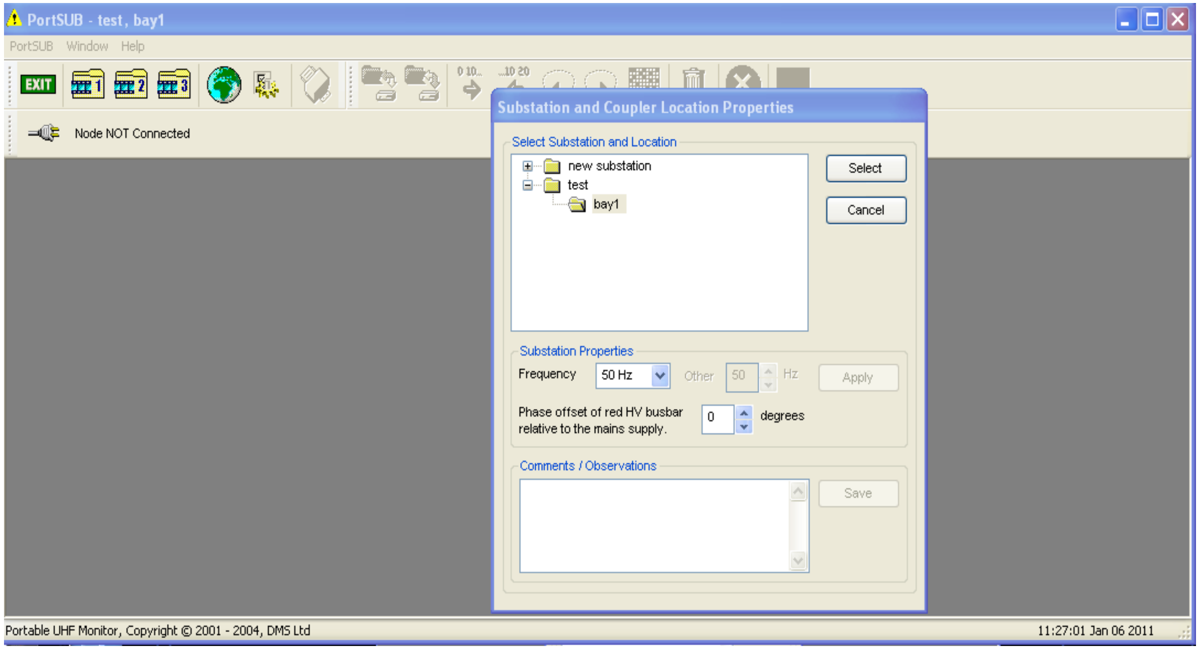
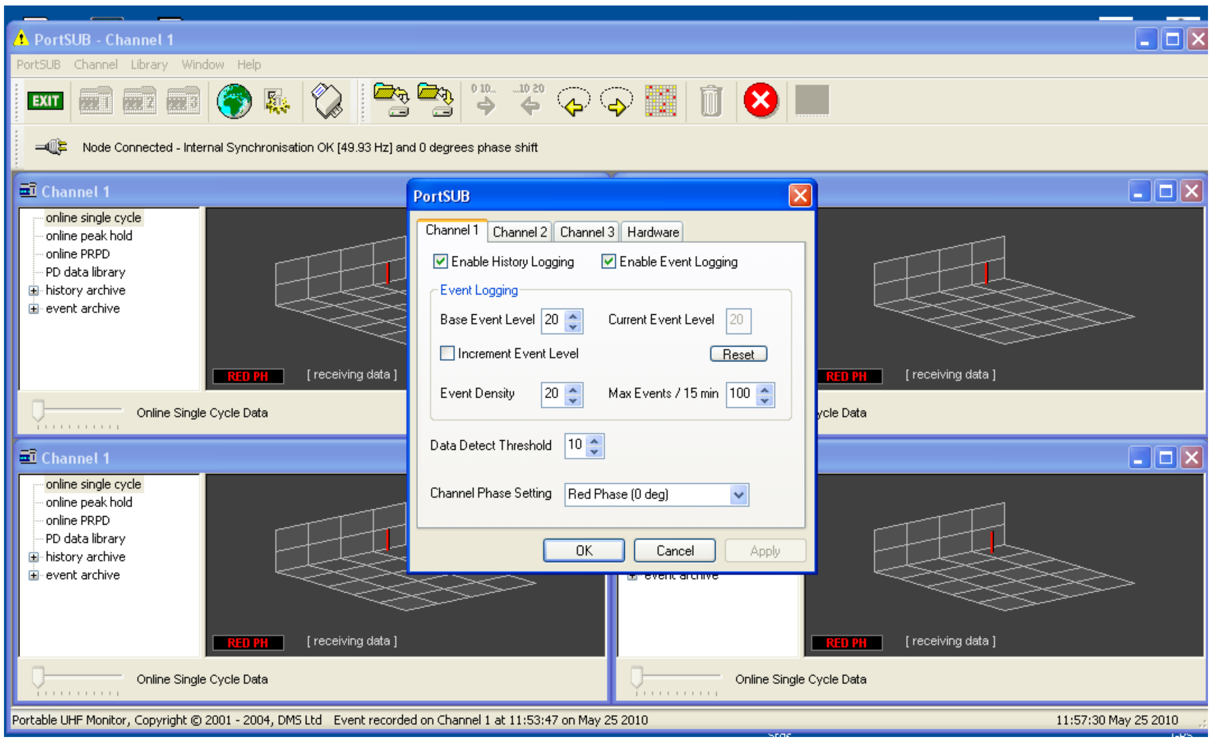
PDM System Overview
Software

PortSUB Substation Properties



PDM System Overview Software

PortSUB System Properties



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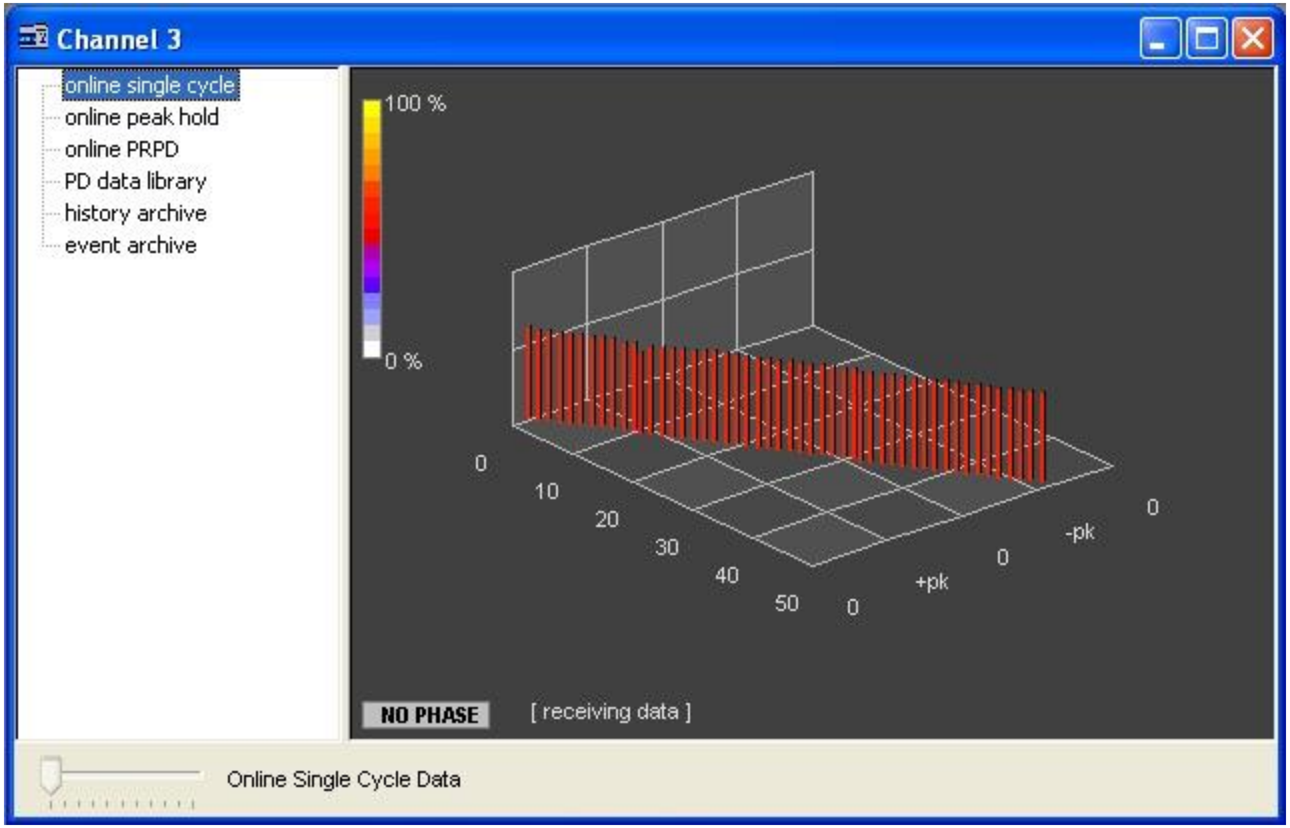
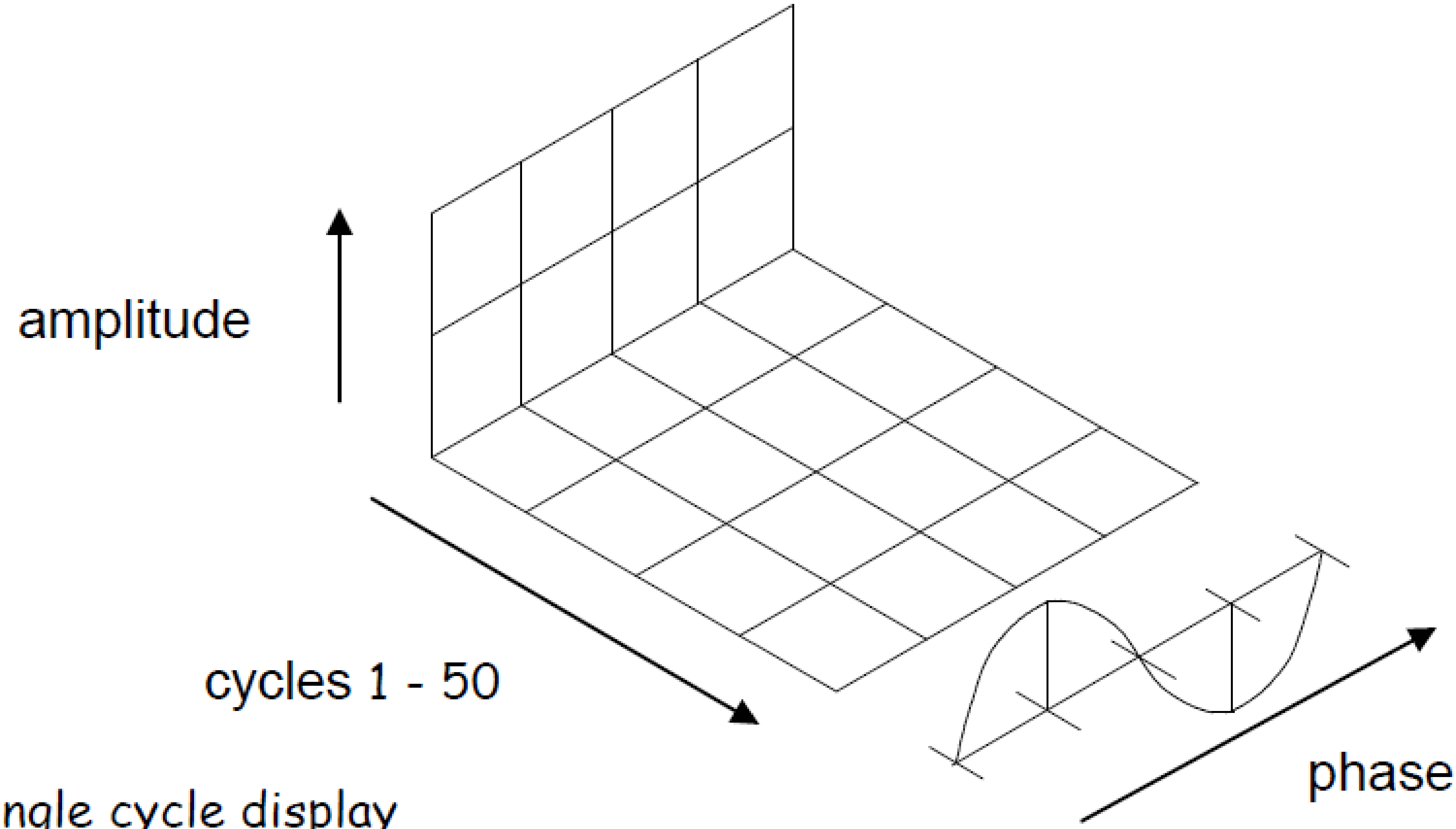
Single cycle display

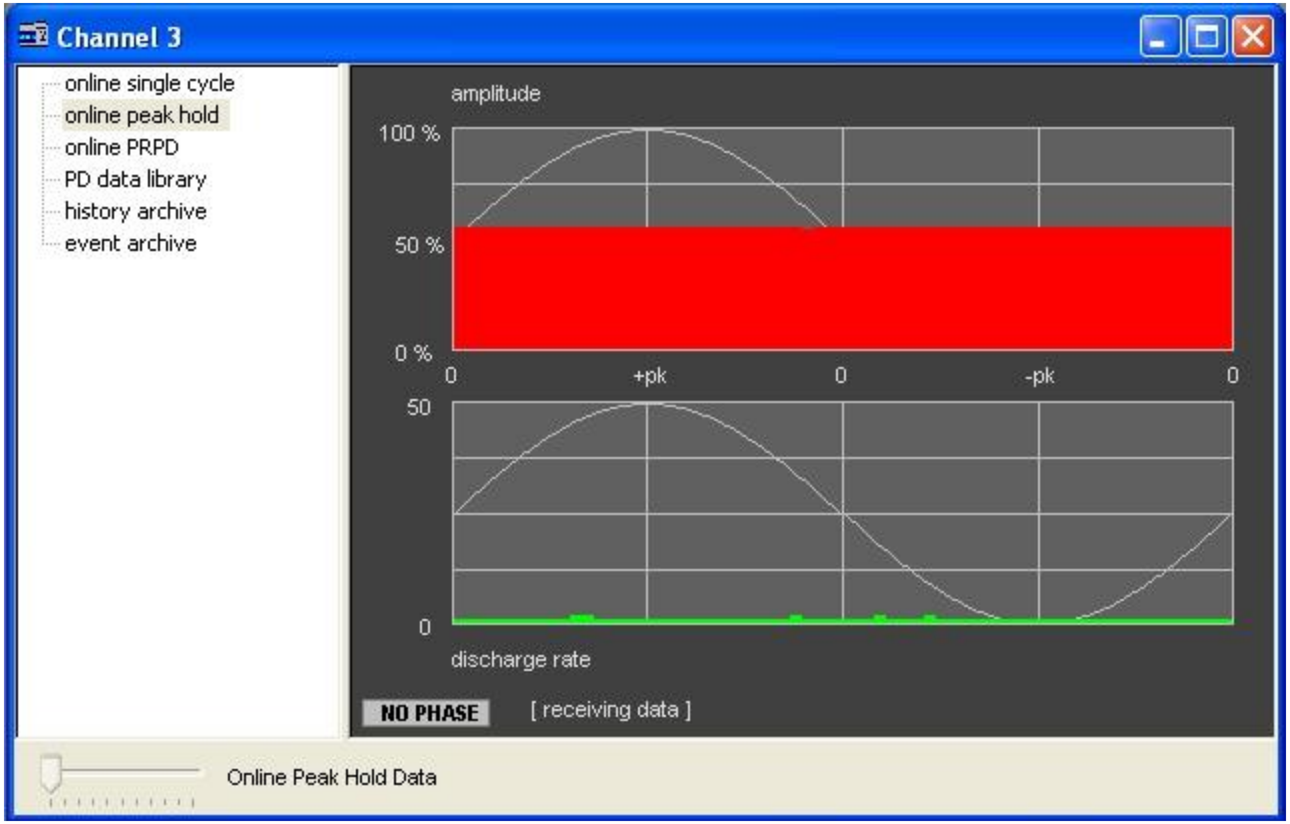


Single cycle display

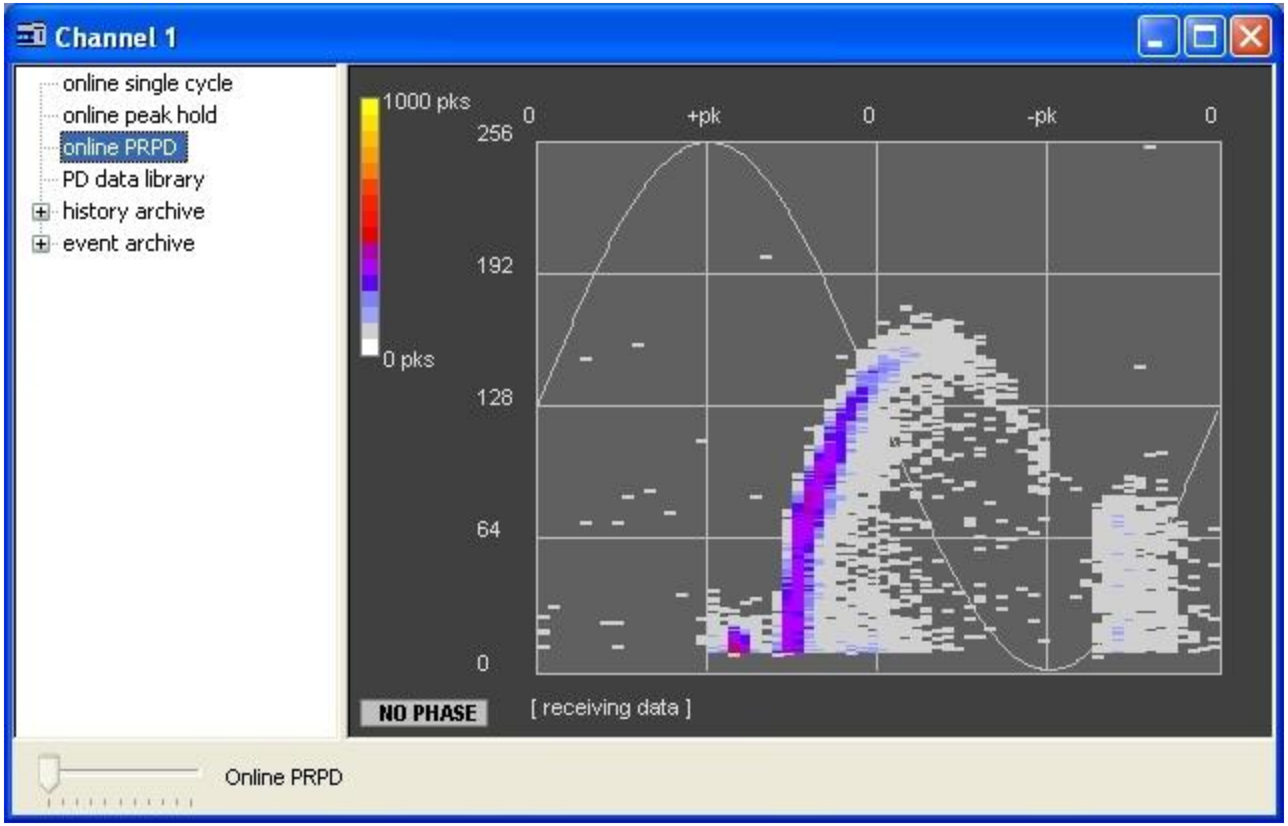


Single cycle display

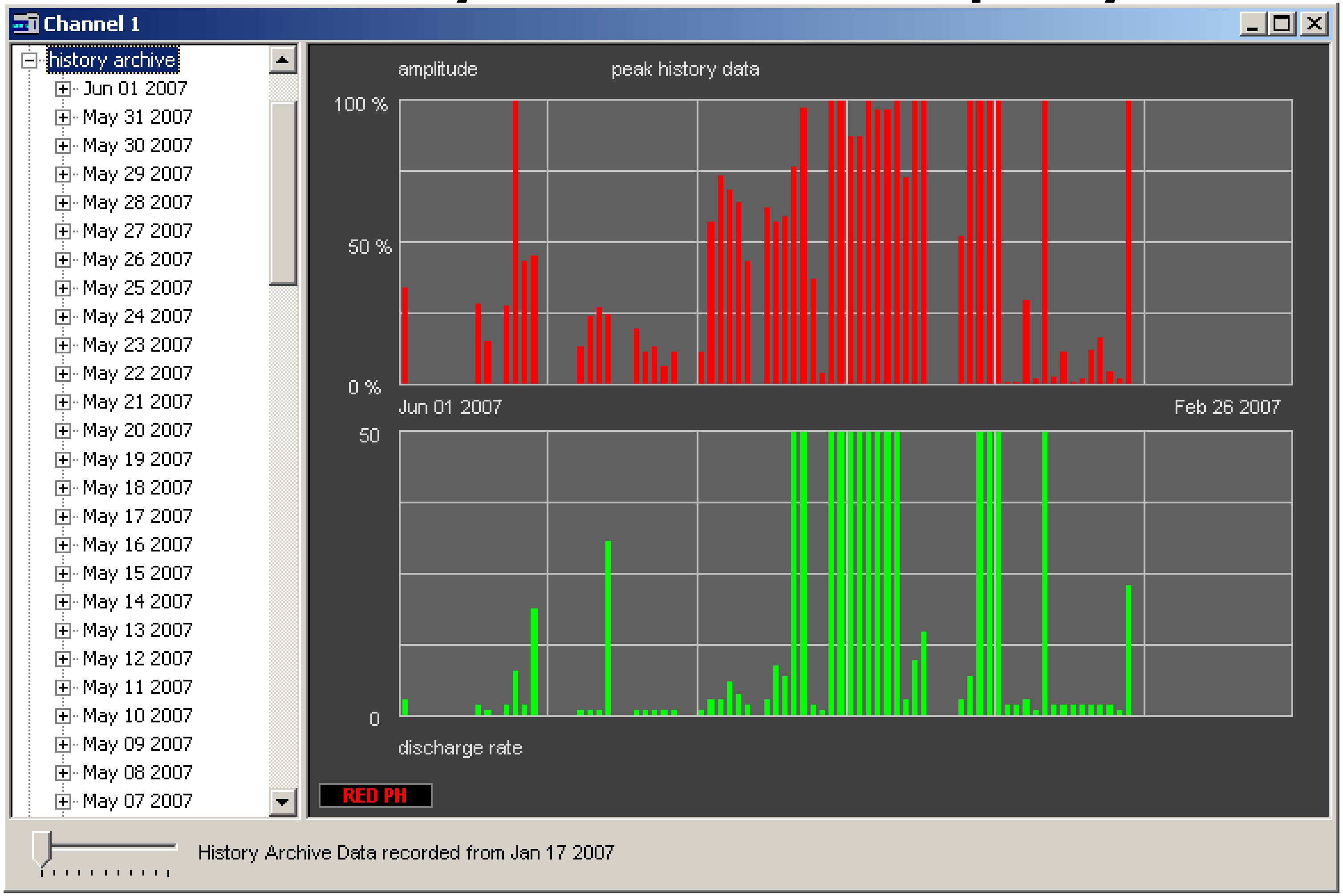
Peak hold display



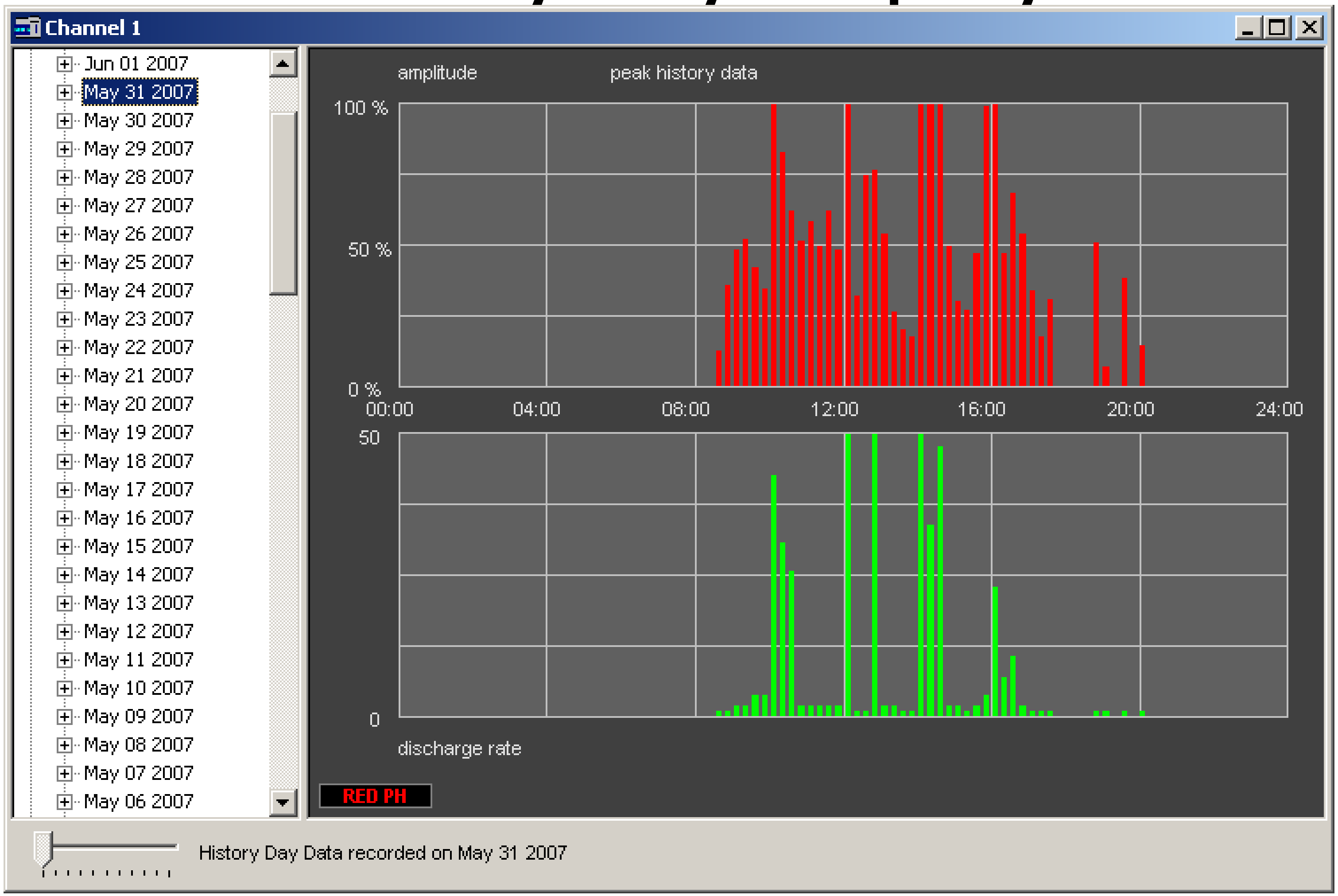
PRPD display



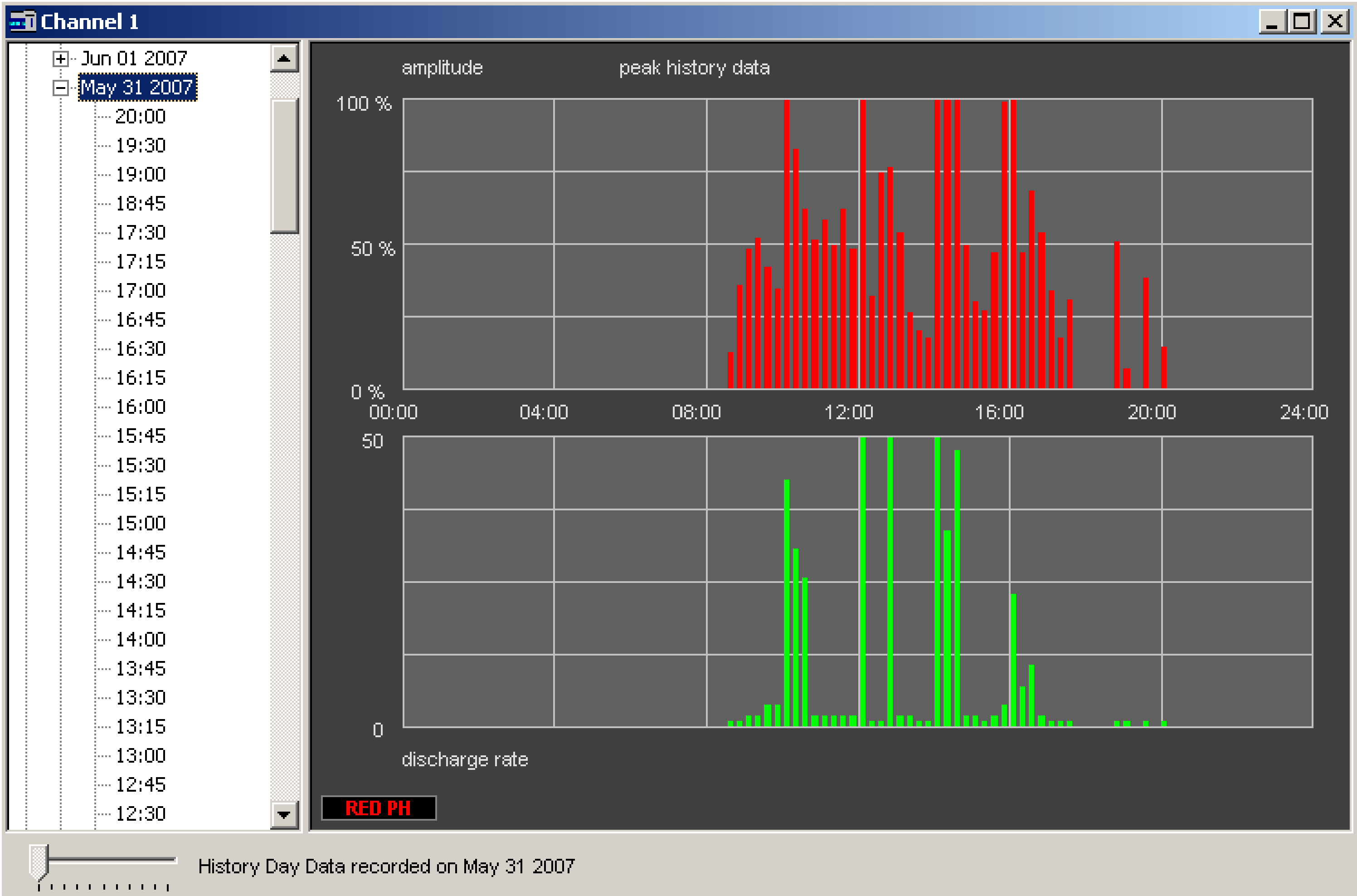
History archive display



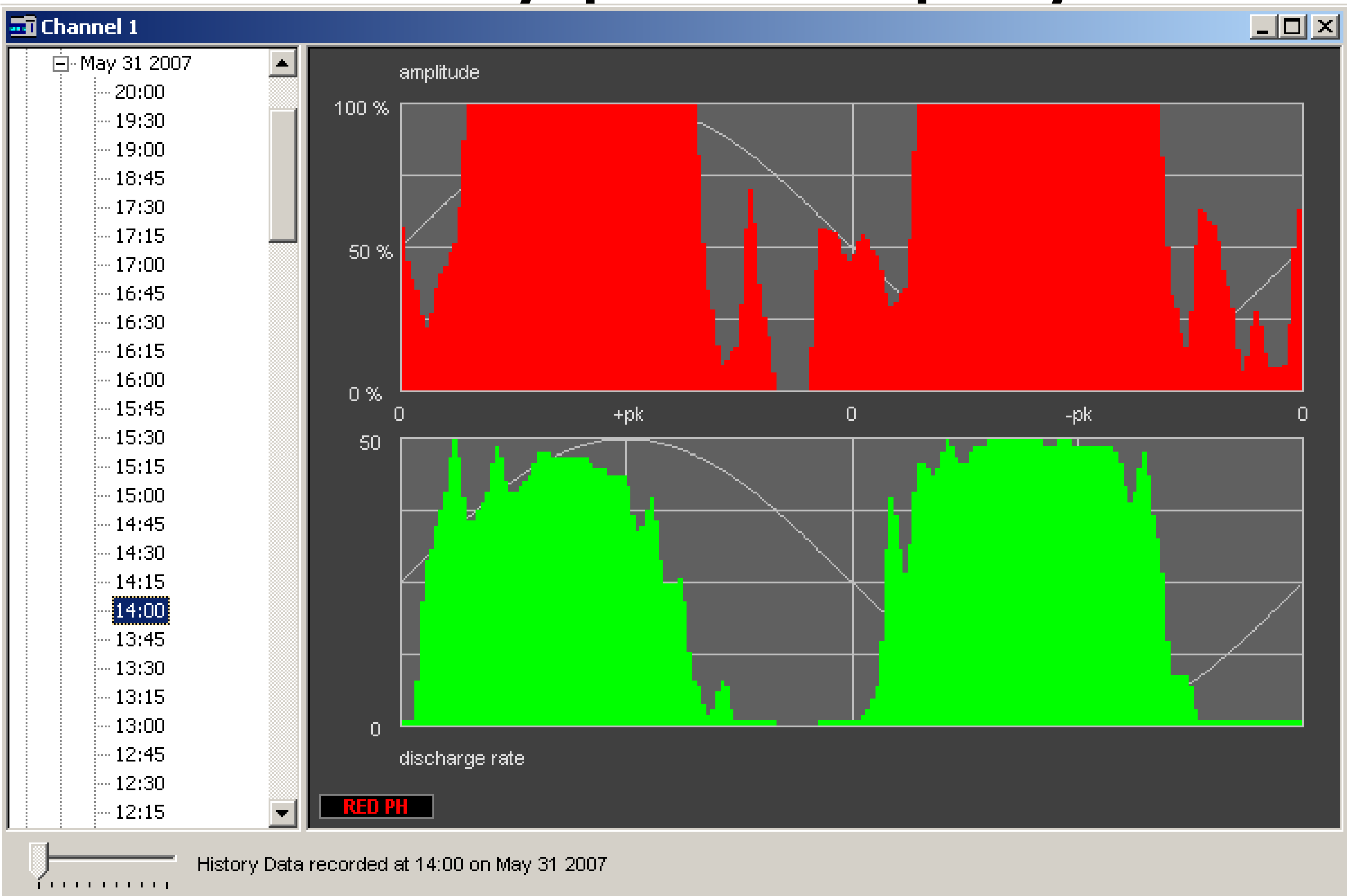
History day display



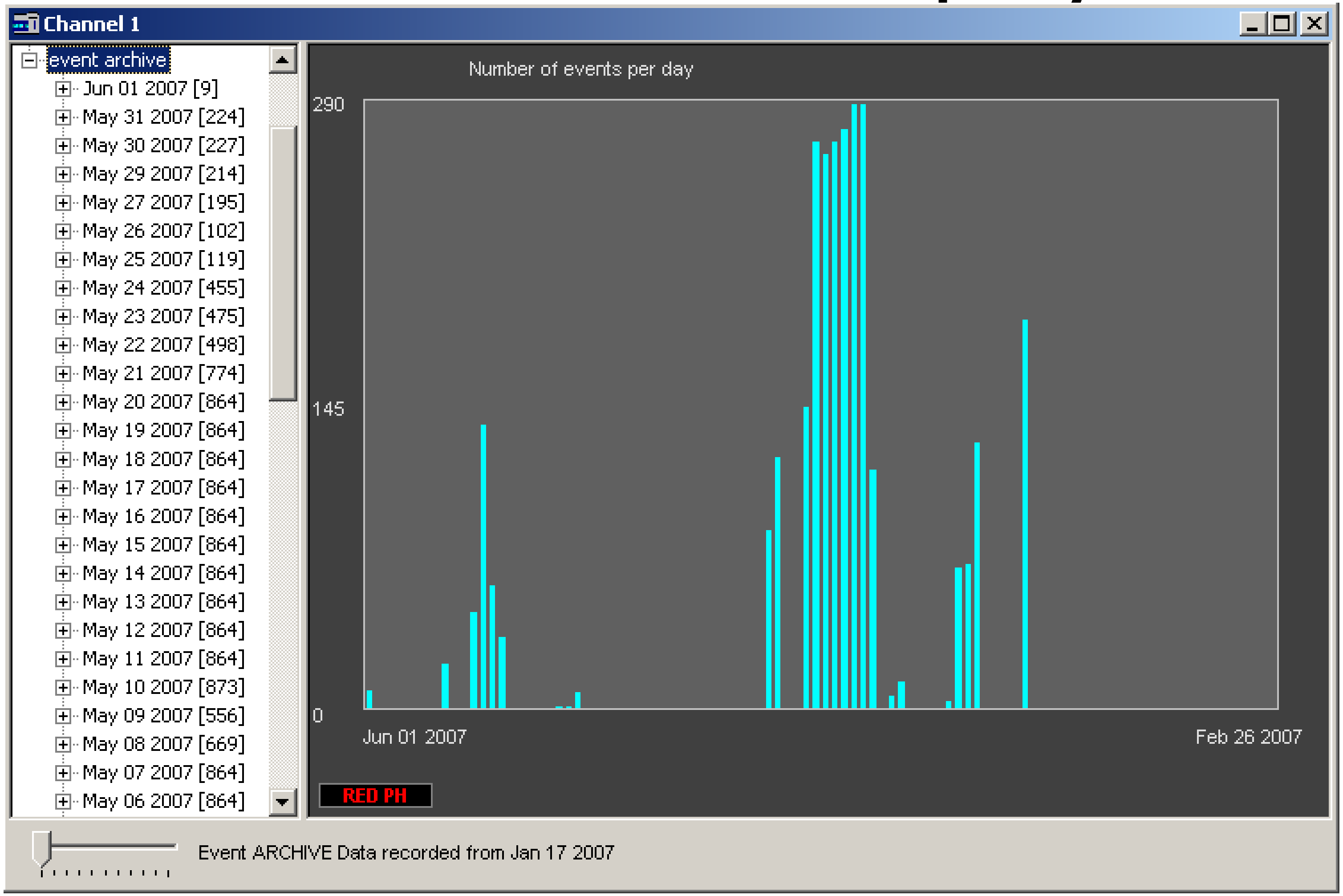
History day display



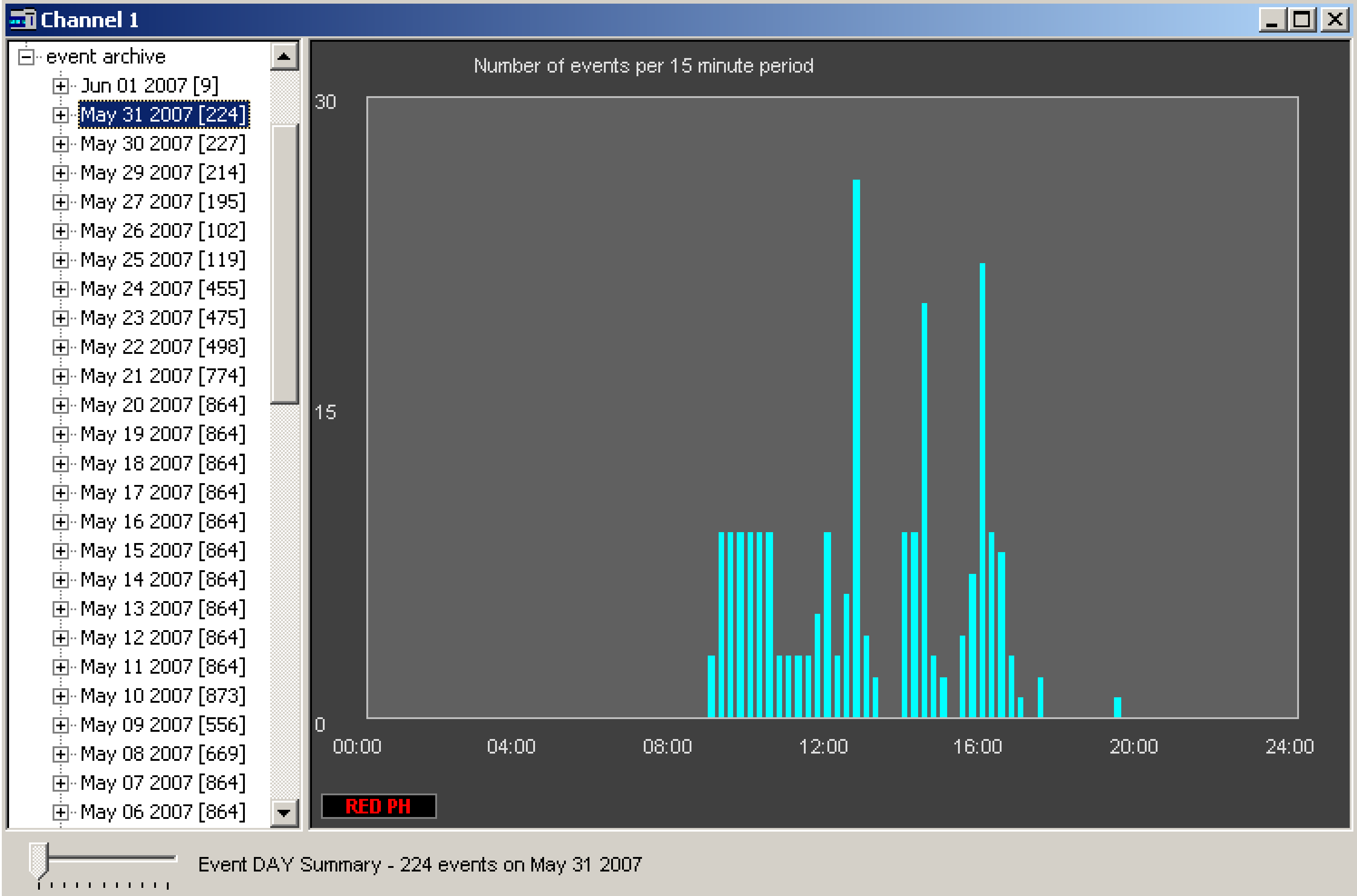
History pow display



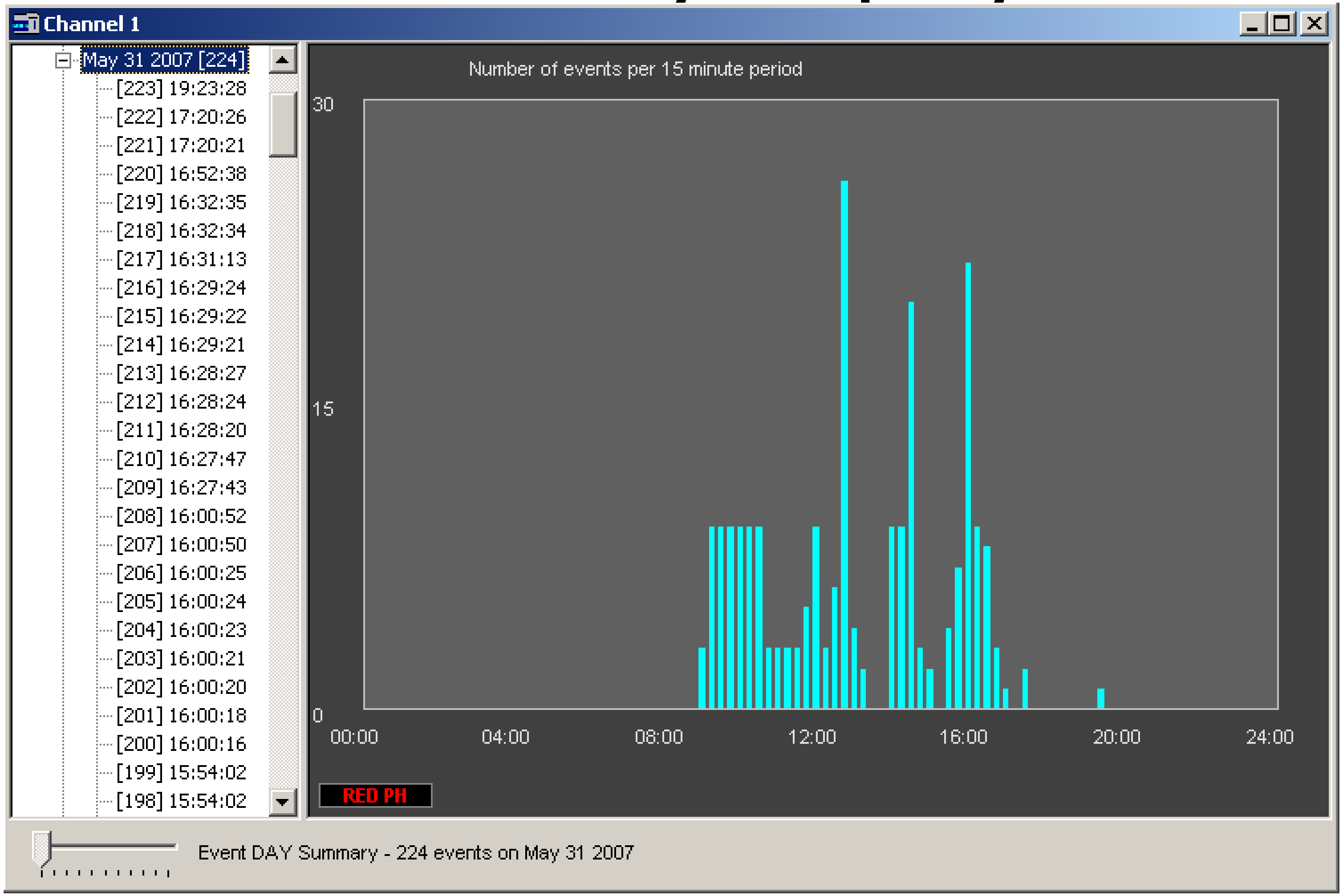
Event archive display



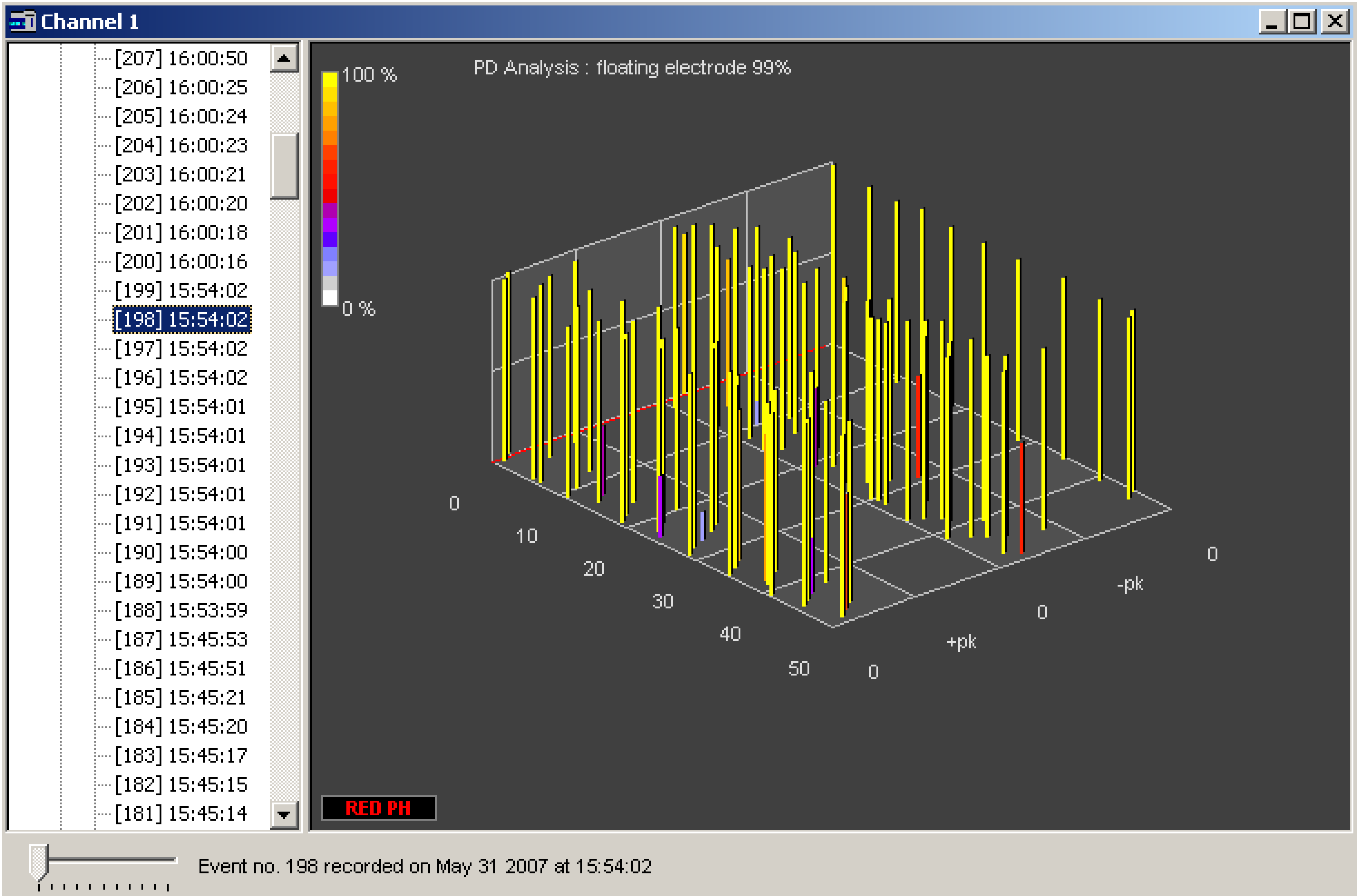
Event day display



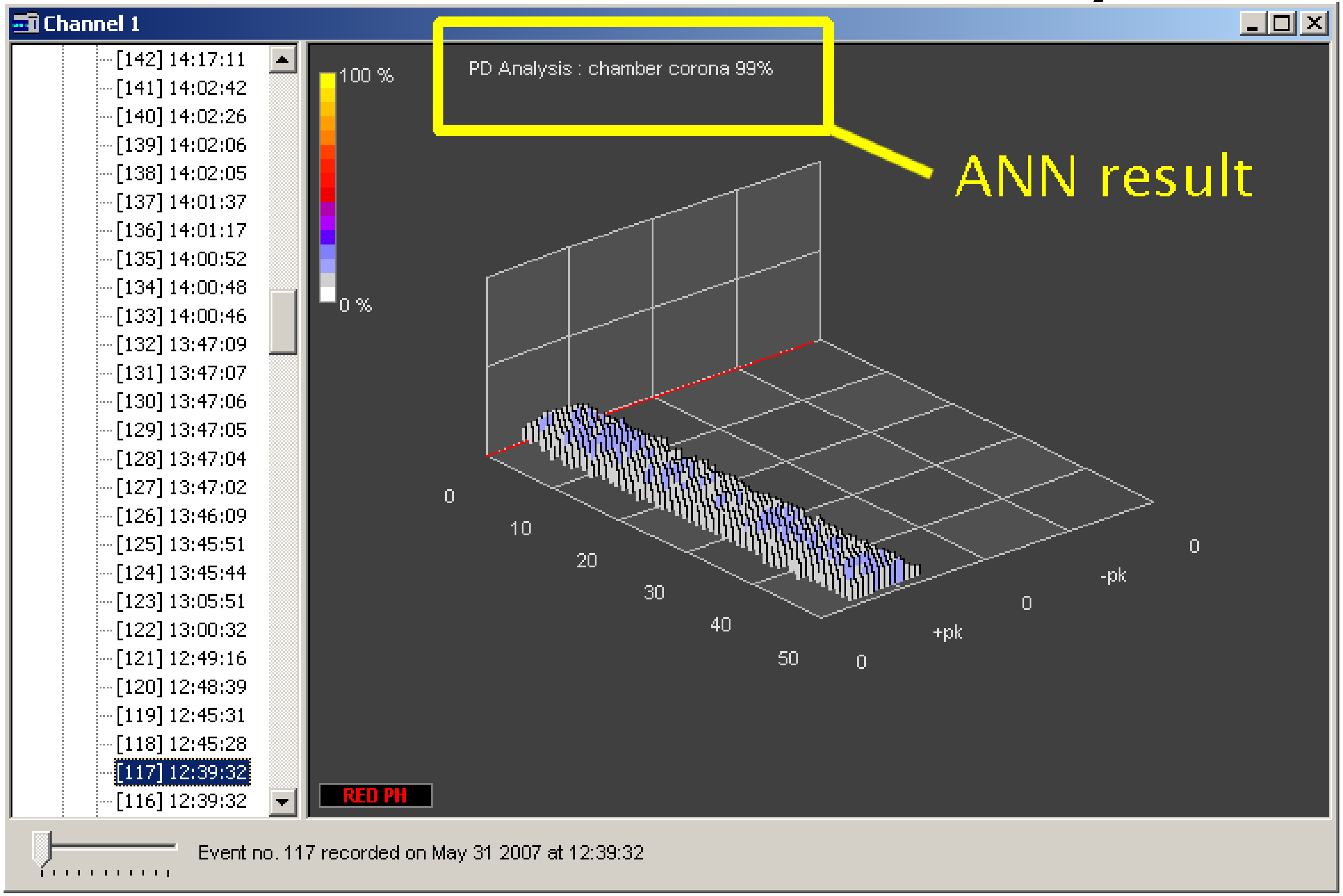
Event day display



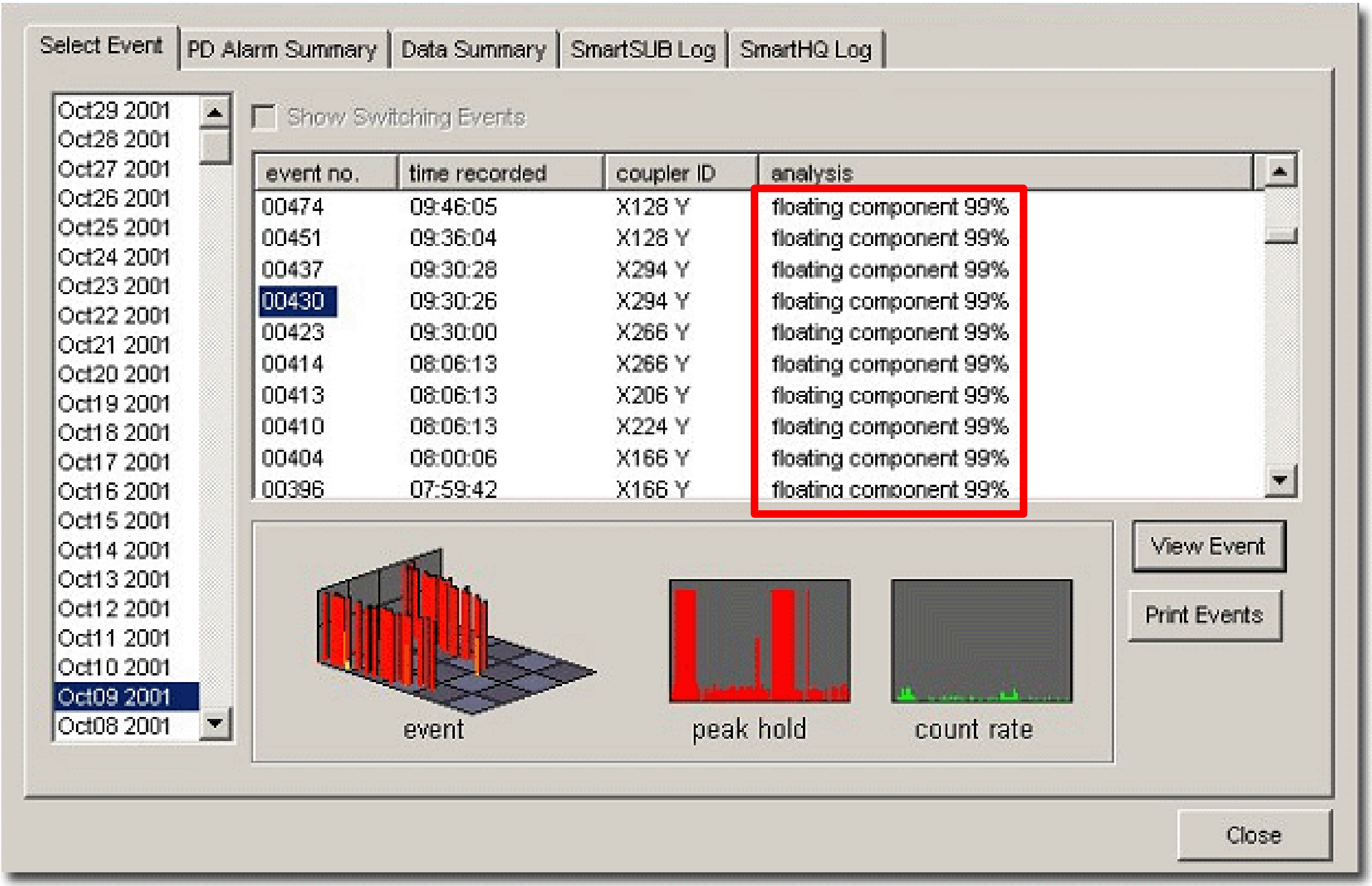
Event record display



Event window with analysis



Event Window With Analysis



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Radial PDM Data Interpretation

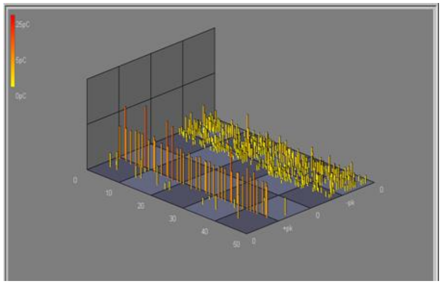
- PD patterns can be very complex, especially in the presence of noise
- Expert skills are needed to correctly interpret the patterns to classify the type of PD
- Most equipment users do not want to be PD experts, so help is needed in this analysis
- The PDM offers the user an expert software that can successfully classify PD
- This system is one of the core products of DMS that has proved to be superior to all competitors

Radial PDM Automatic Data Interpretation

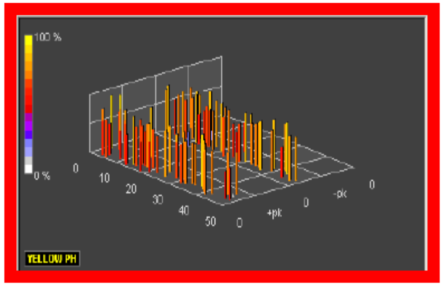
- The DMS expert system uses various proven software techniques to classify PD
- Advanced Artificial Neural Network (ANN) algorithms for PD type identification
- Algorithm removes interference from mobile phones, switching, lights, etc.
- ANN is trained using a database containing 15 years of site and lab data

Radial PDM System Data Displays

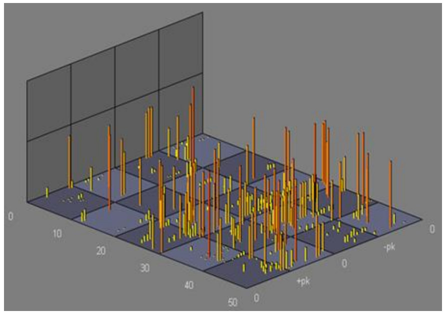
Conductor Surface



Floating Component

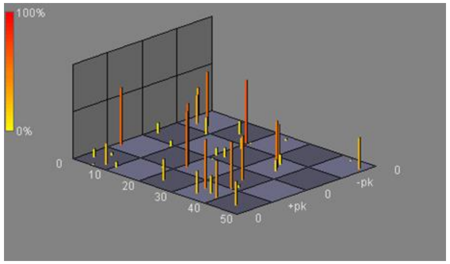


Defective Discharge Lamp



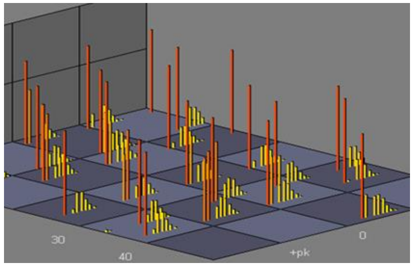
Real PD

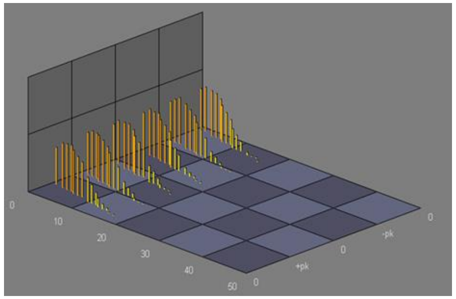
Noise



Hopping Particle

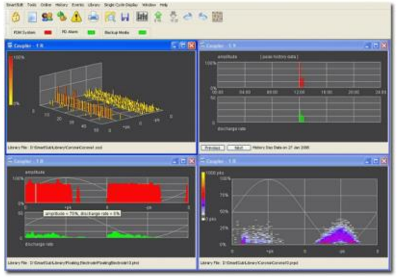
Mobile Phone





RADAR

Radial PDM Artificial Neural Network



2D + 3D
discharge
data

Location of PD in GIS

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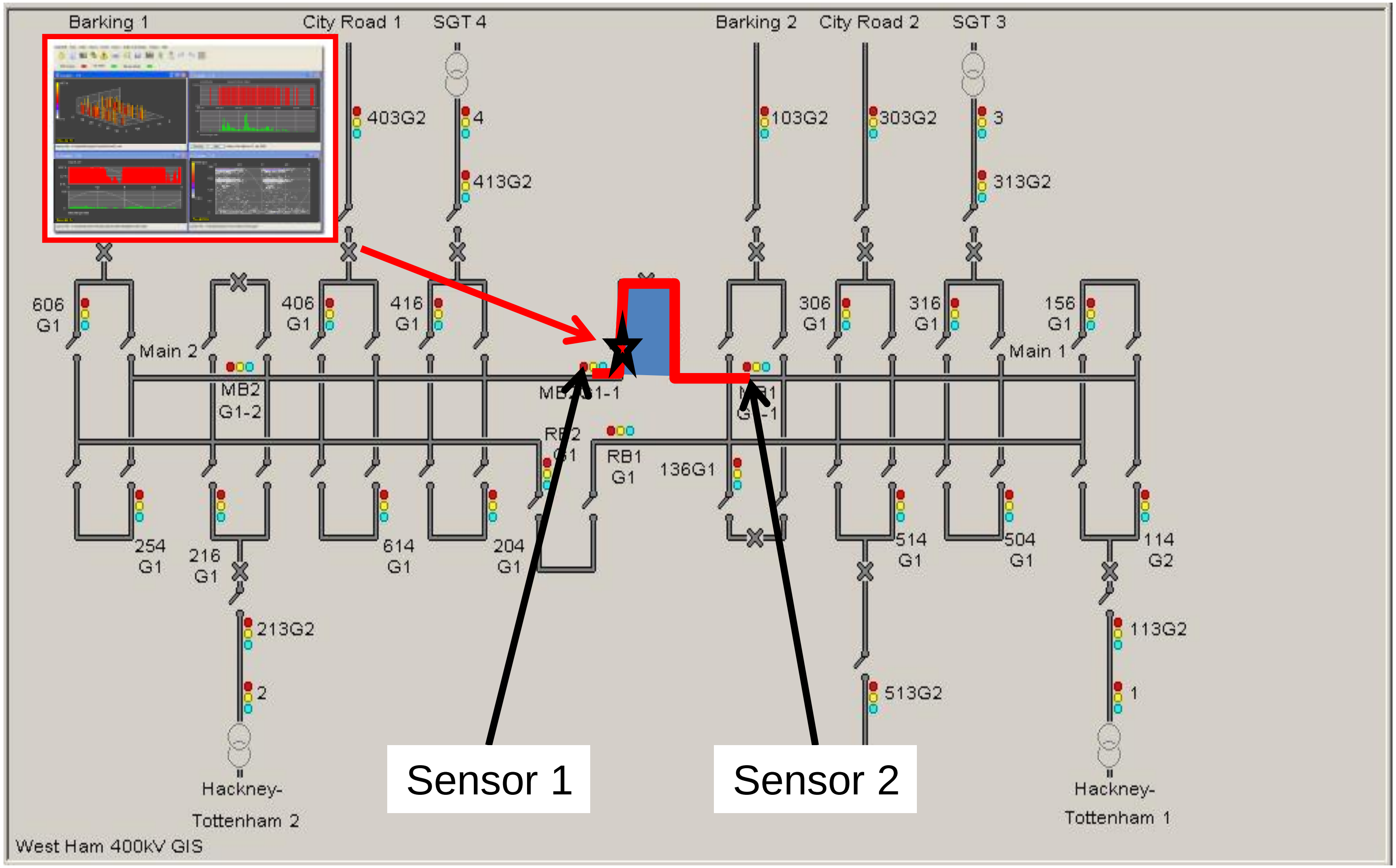
PD Location on Single-Line-Diagram



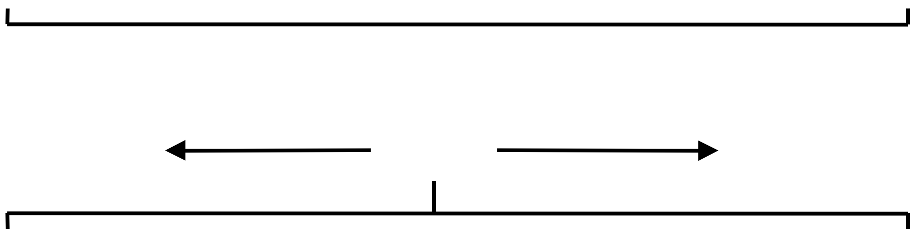
(SLD courtesy of NGC)

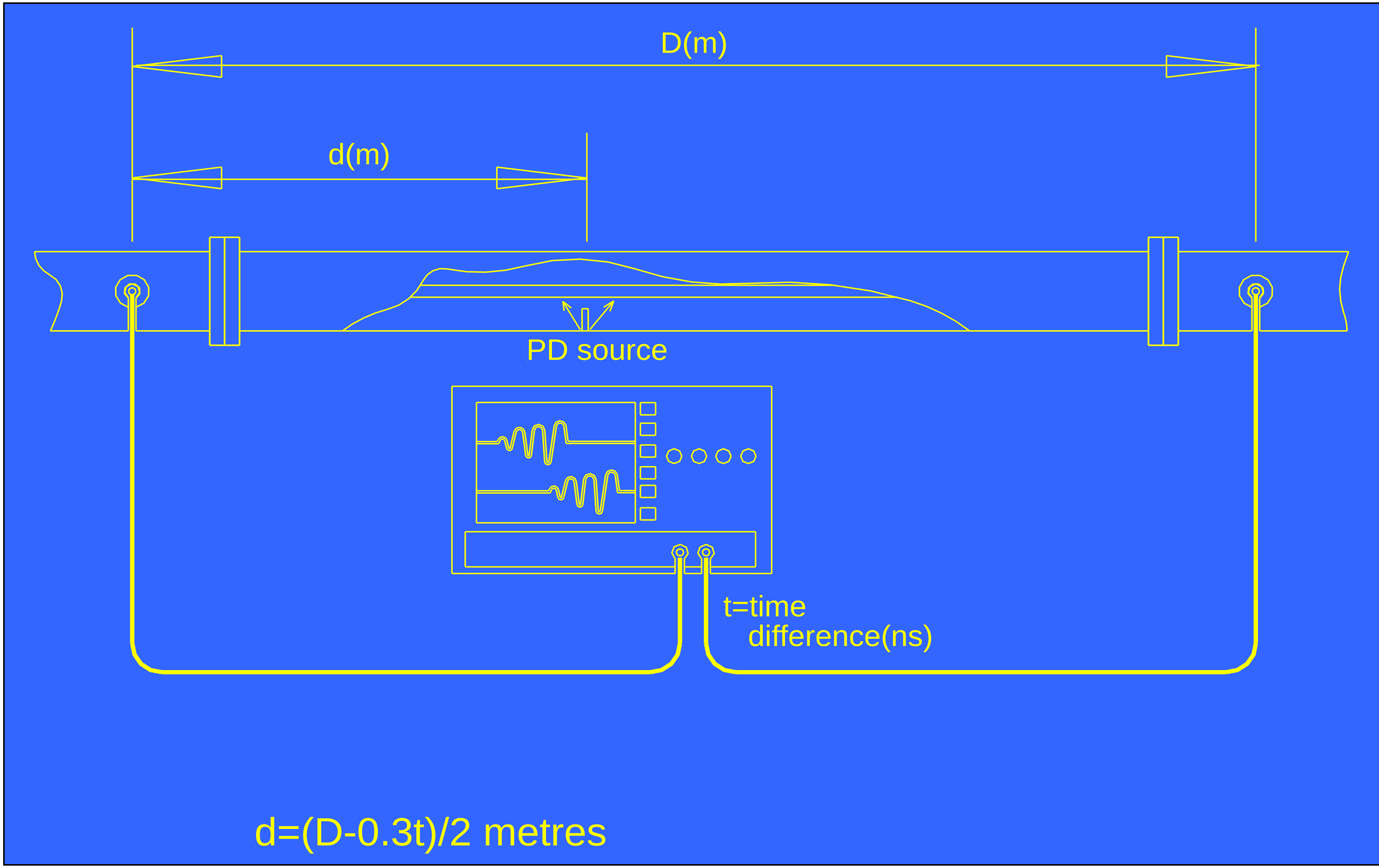
UHF PD pulses travel at the speed of light inside the GIS and an electromagnetic wave.

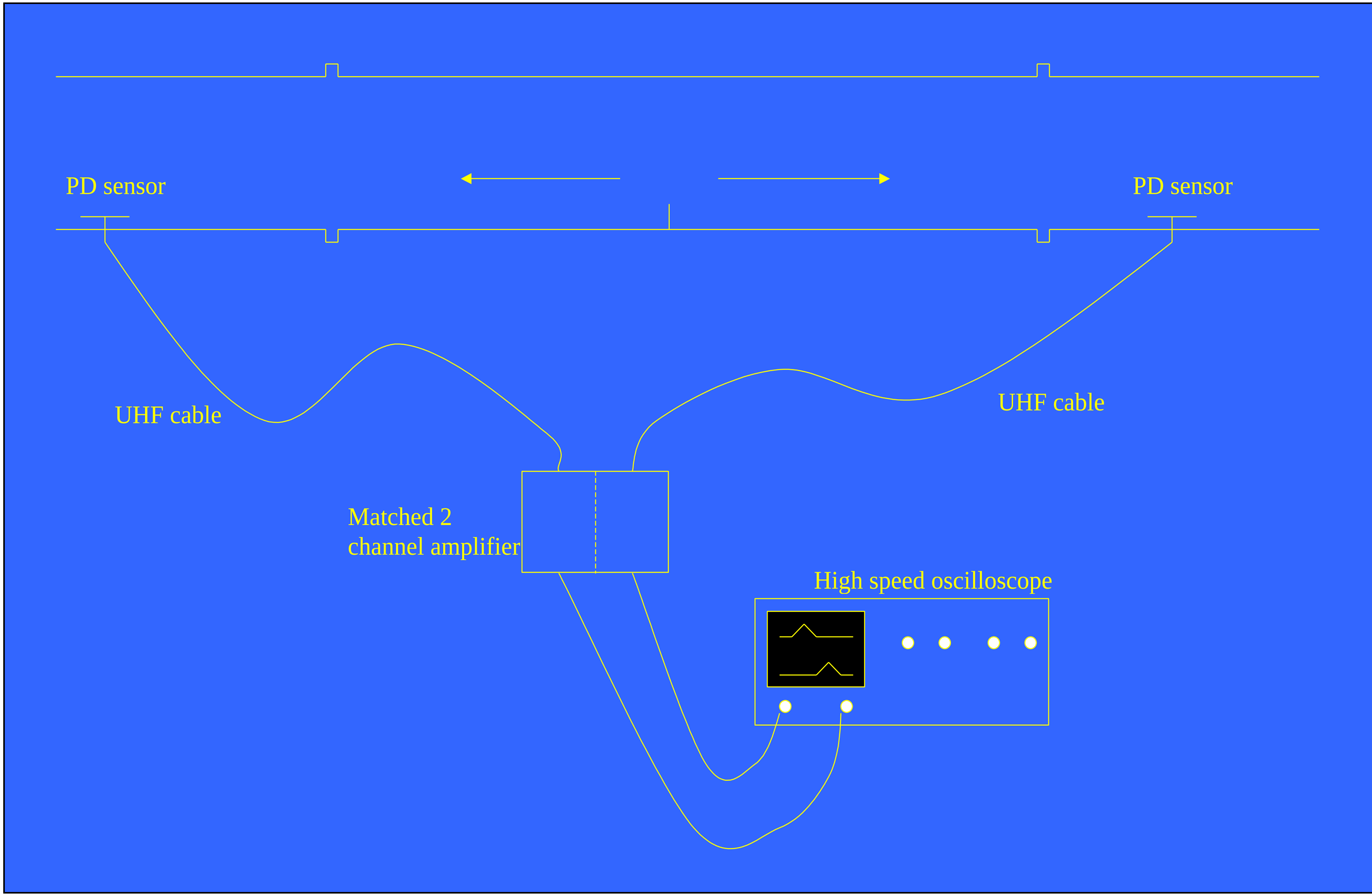
Speed of light =300,000,000 m/s
=300 m/µs
= 0.3 m/ns

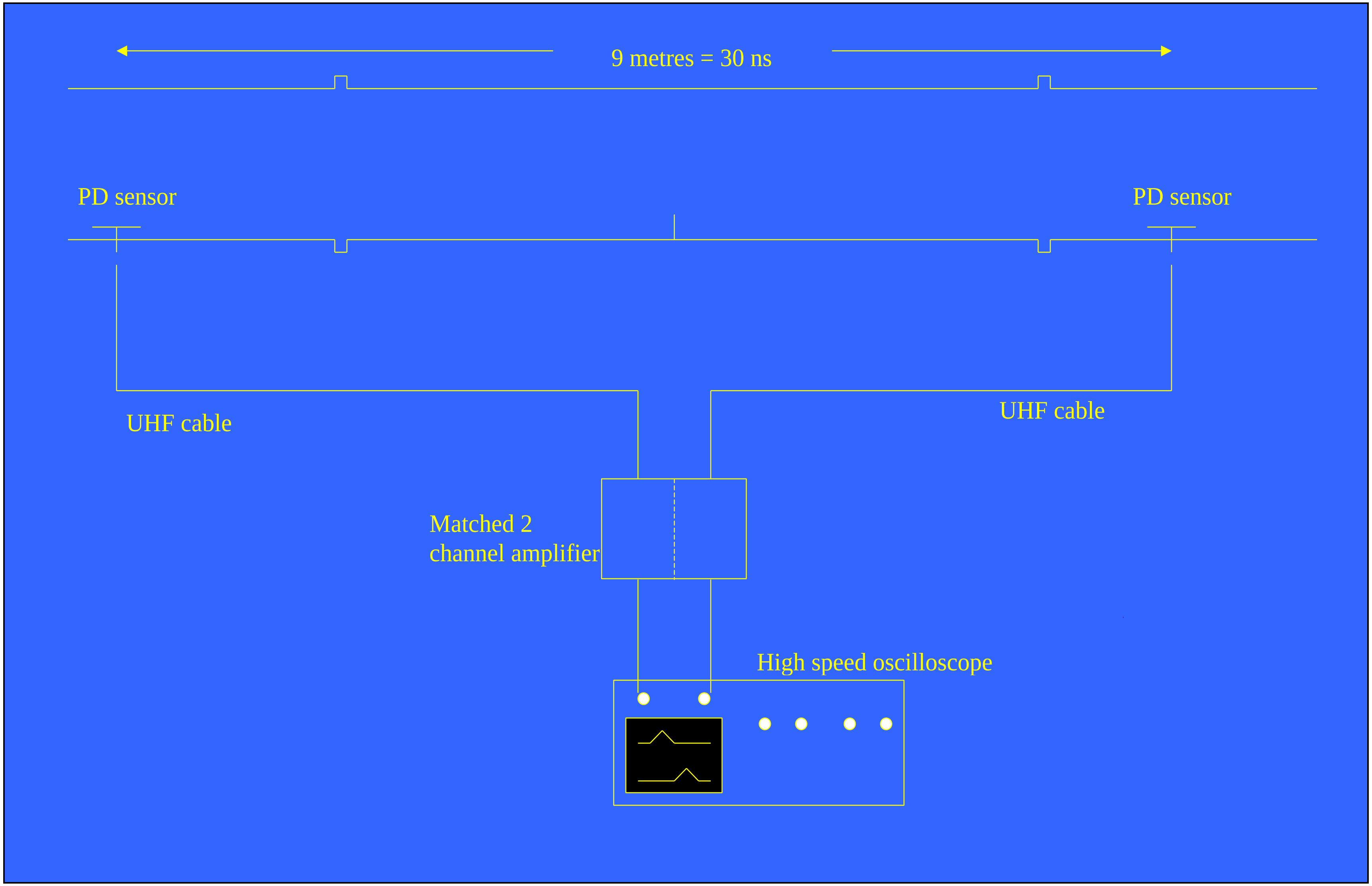
This means it travels 1m every 3.3ns.

The pulse travels in both directions along the GIS away from the PD

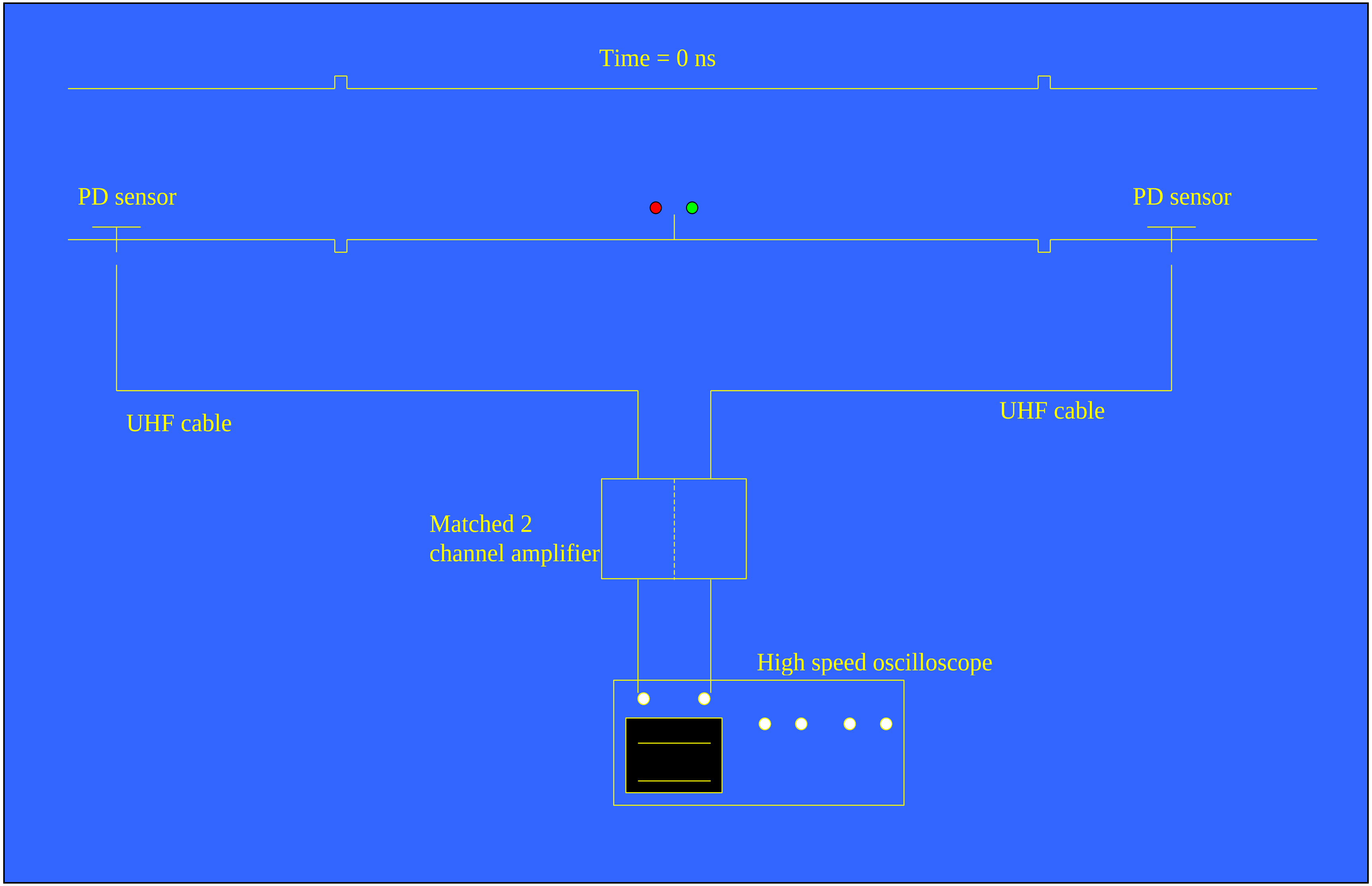


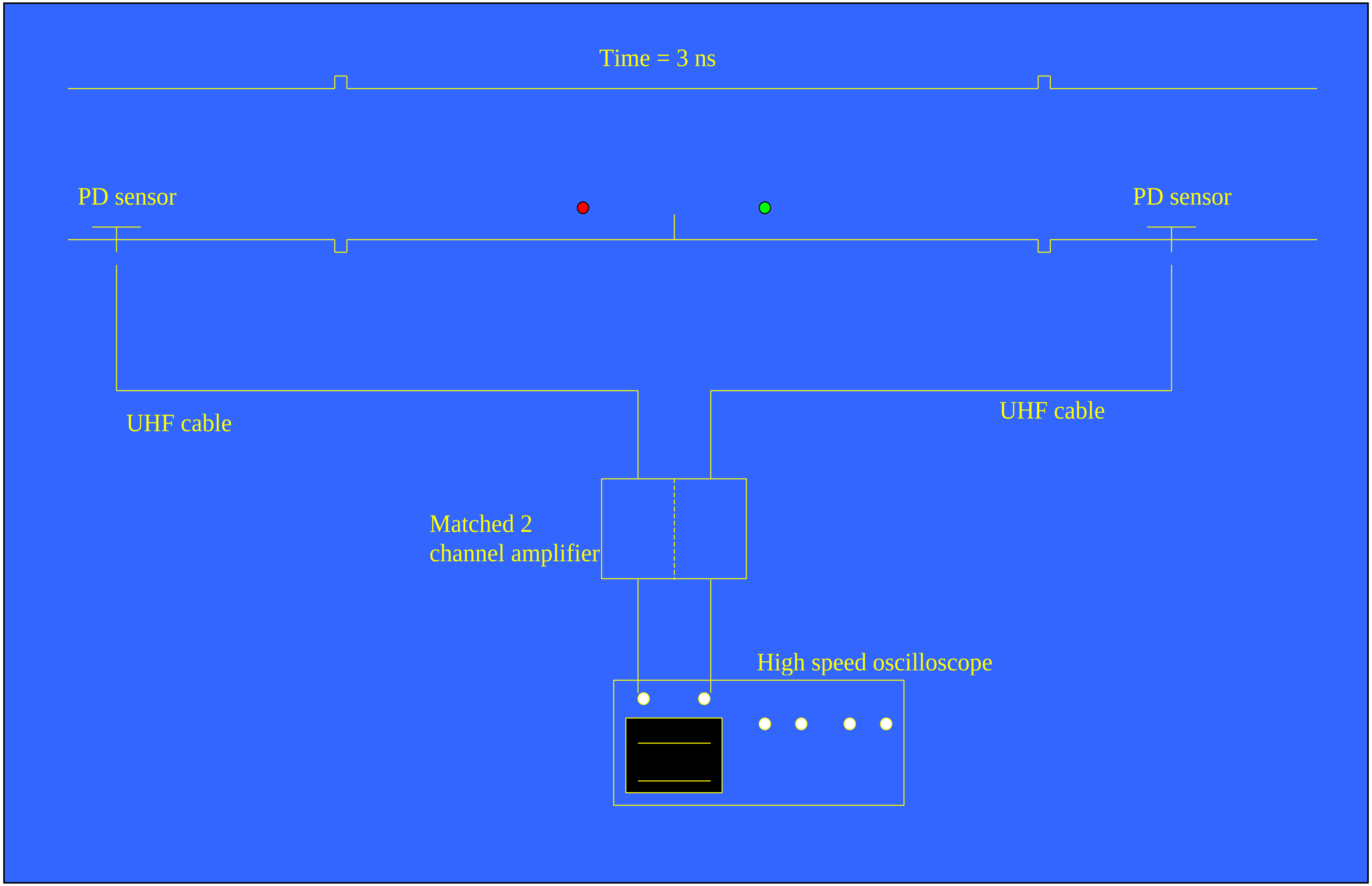

D(m)
d(m)
PD source
t=time
difference(ns)
d=(D-0.3t)/2 metres

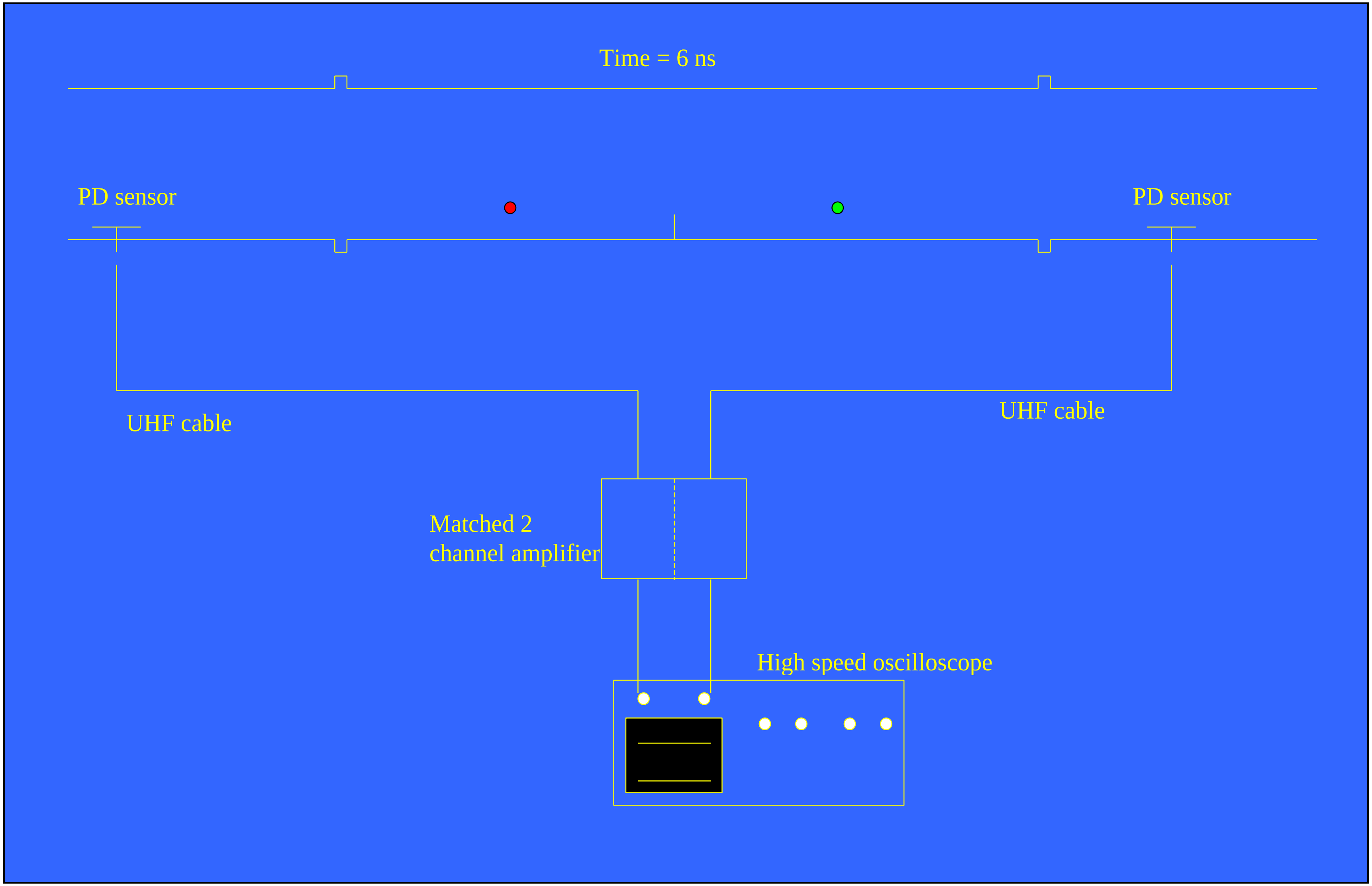

PD sensor
PD sensor
UHF cable
UHF cable
Matched 2
channel amplifier
High speed oscilloscope



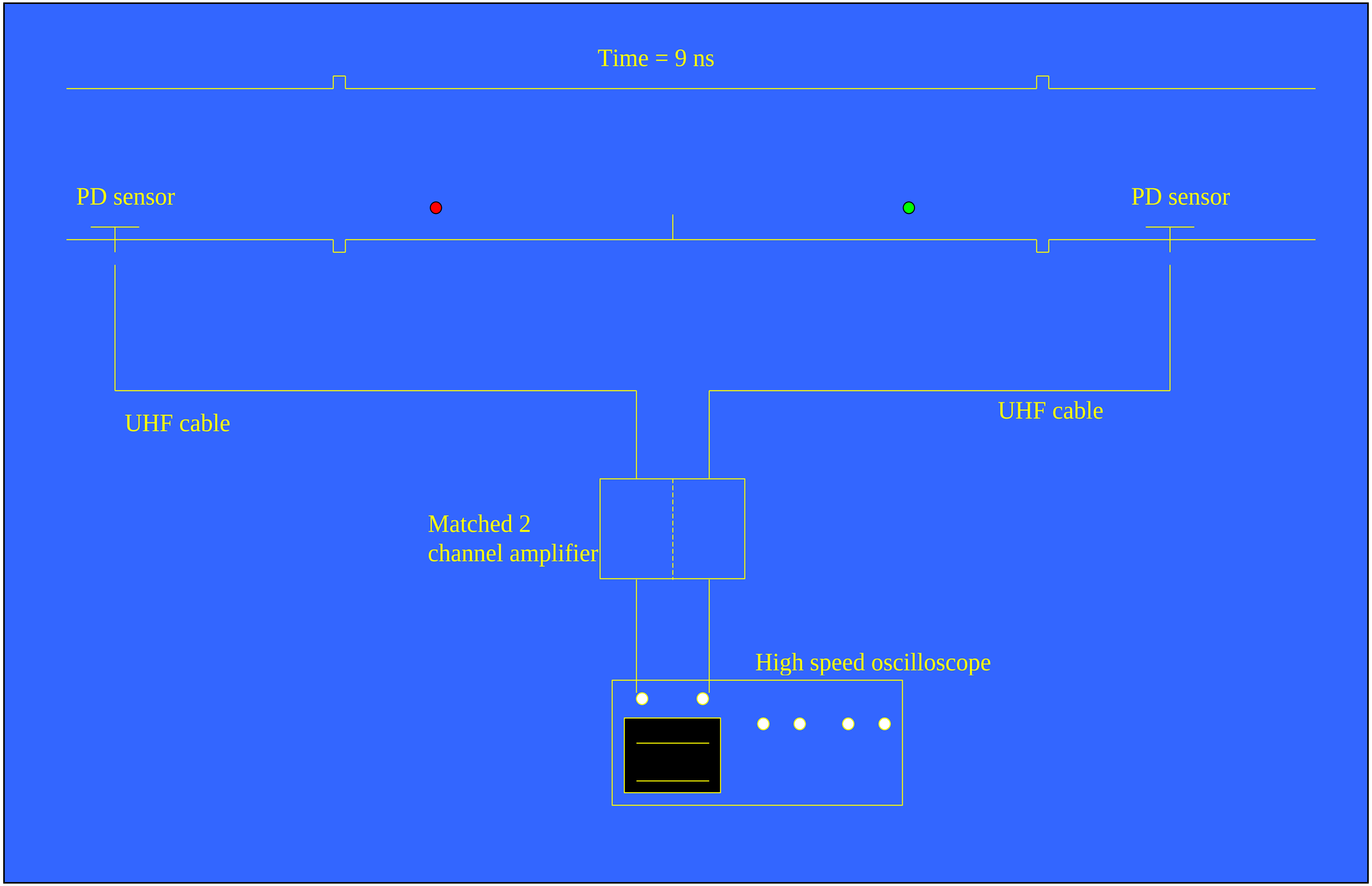
9 metres = 30 ns
PD sensor
PD sensor
UHF cable
UHF cable
Matched 2
channel amplifier
High speed oscilloscope

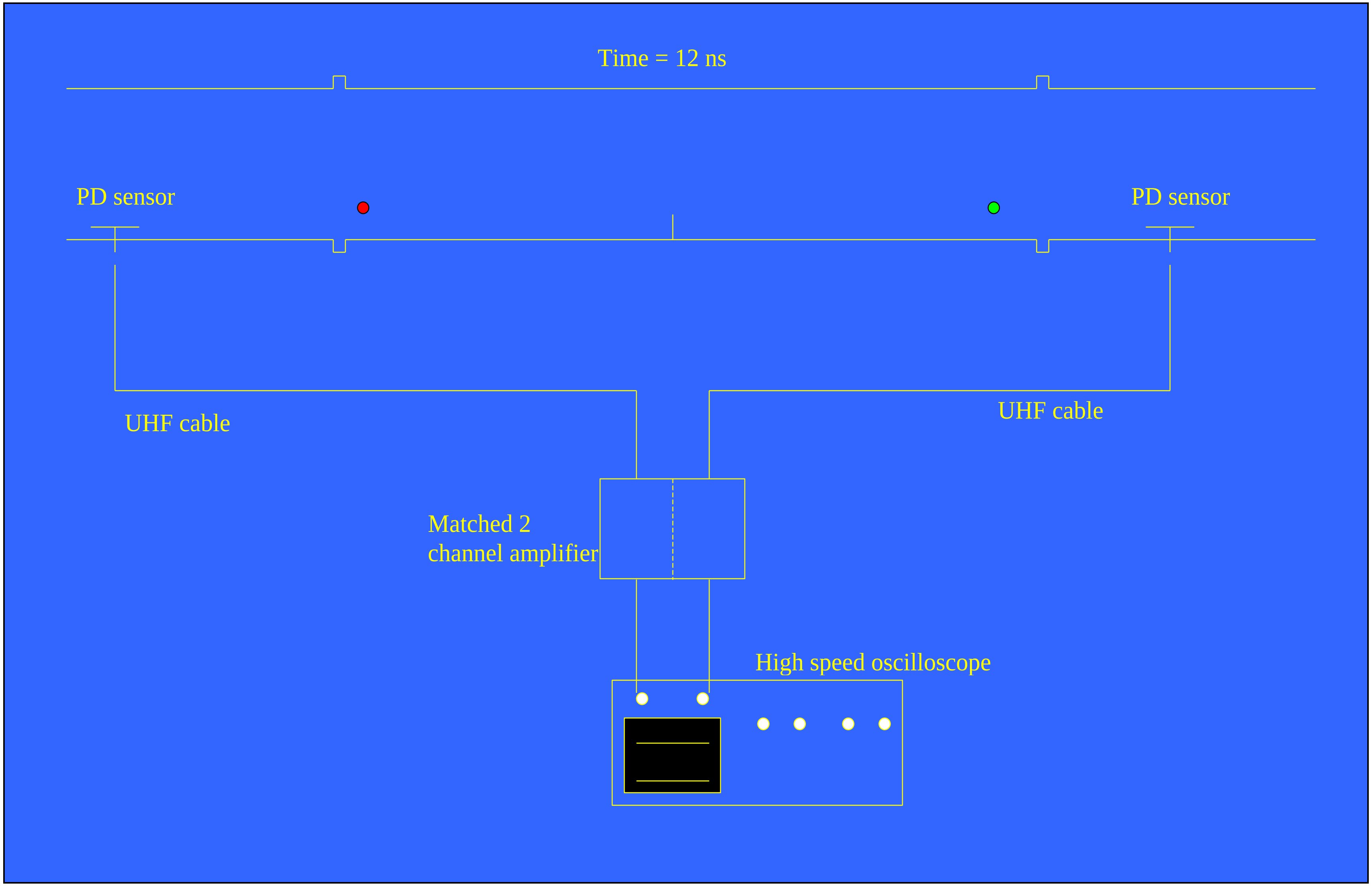

Time = 0 ns
PD sensor
PD sensor
UHF cable
UHF cable
Matched 2
channel amplifier
High speed oscilloscope

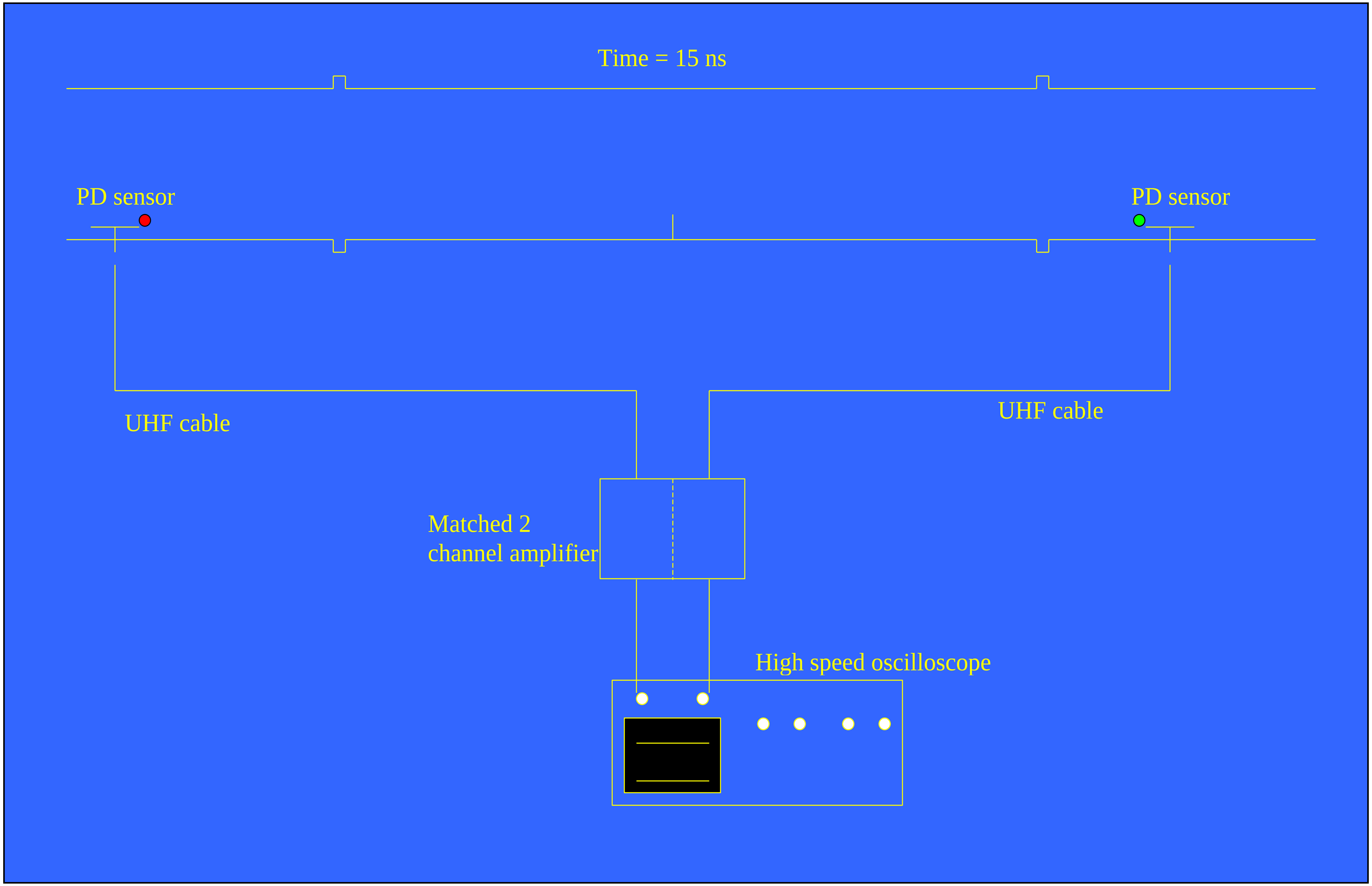

Time = 3 ns
PD sensor
PD sensor
UHF cable
UHF cable
Matched 2
channel amplifier
High speed oscilloscope

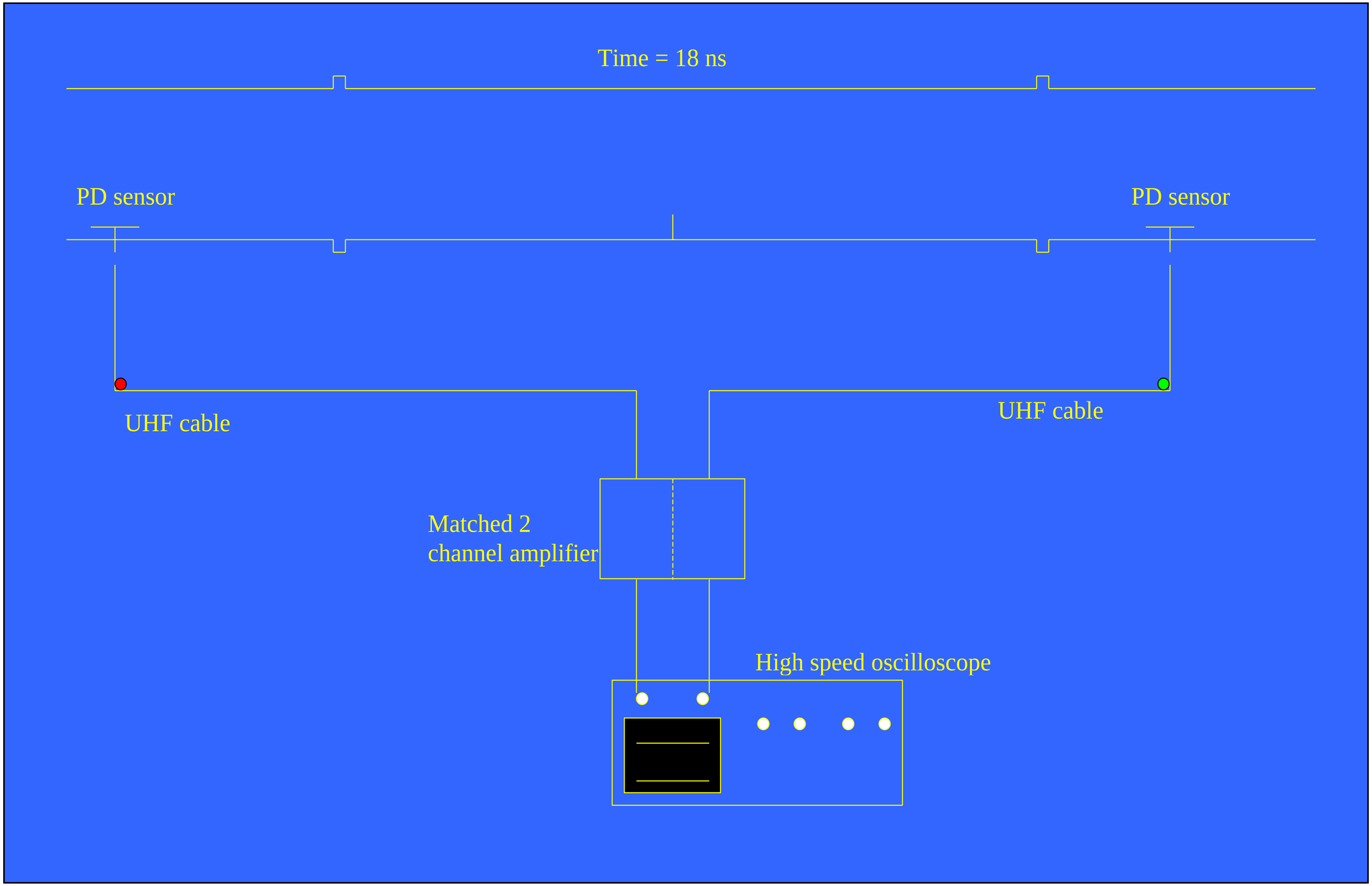


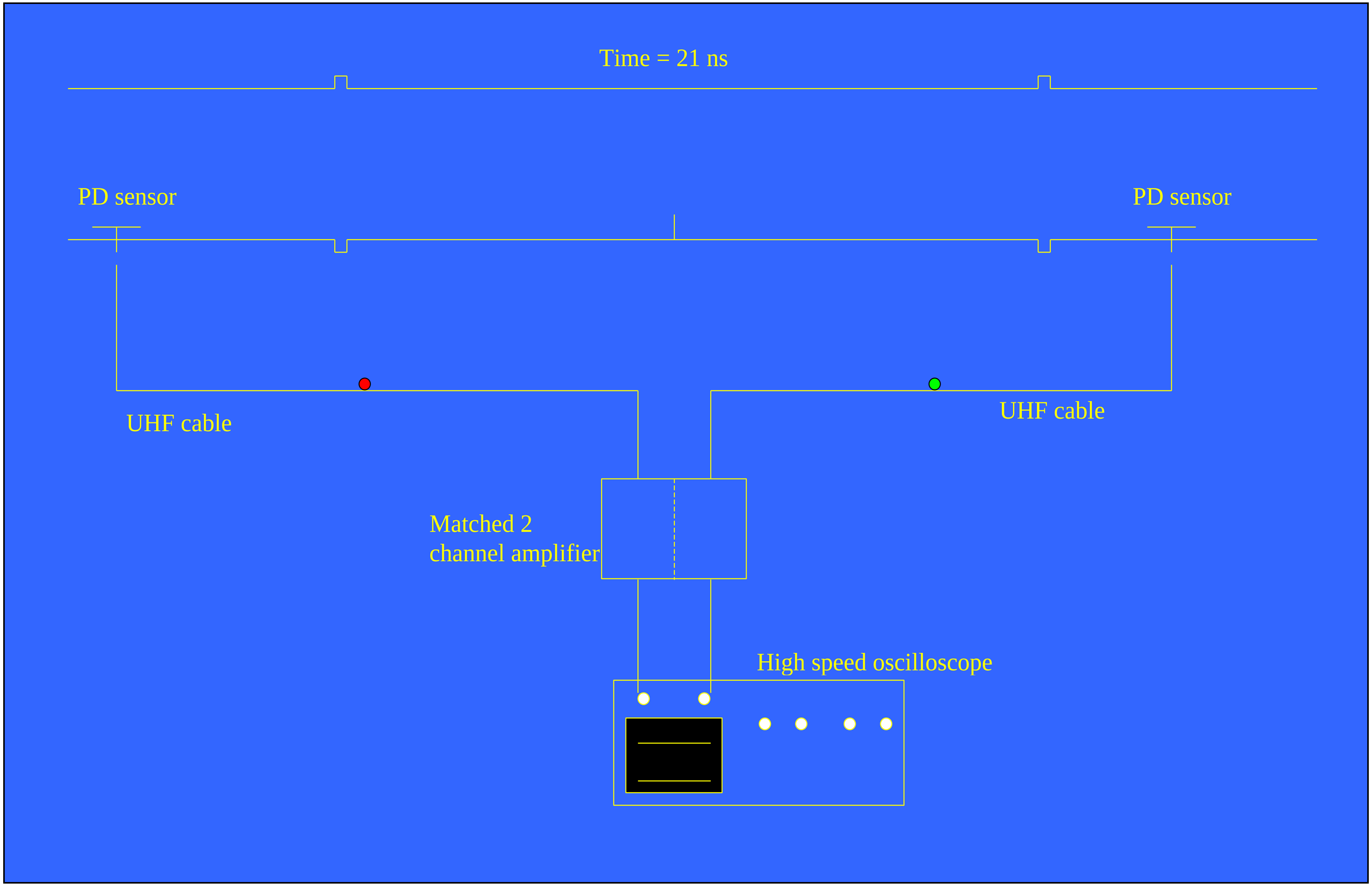
Time = 6 ns
PD sensor
PD sensor
UHF cable
UHF cable
Matched 2
channel amplifier
High speed oscilloscope

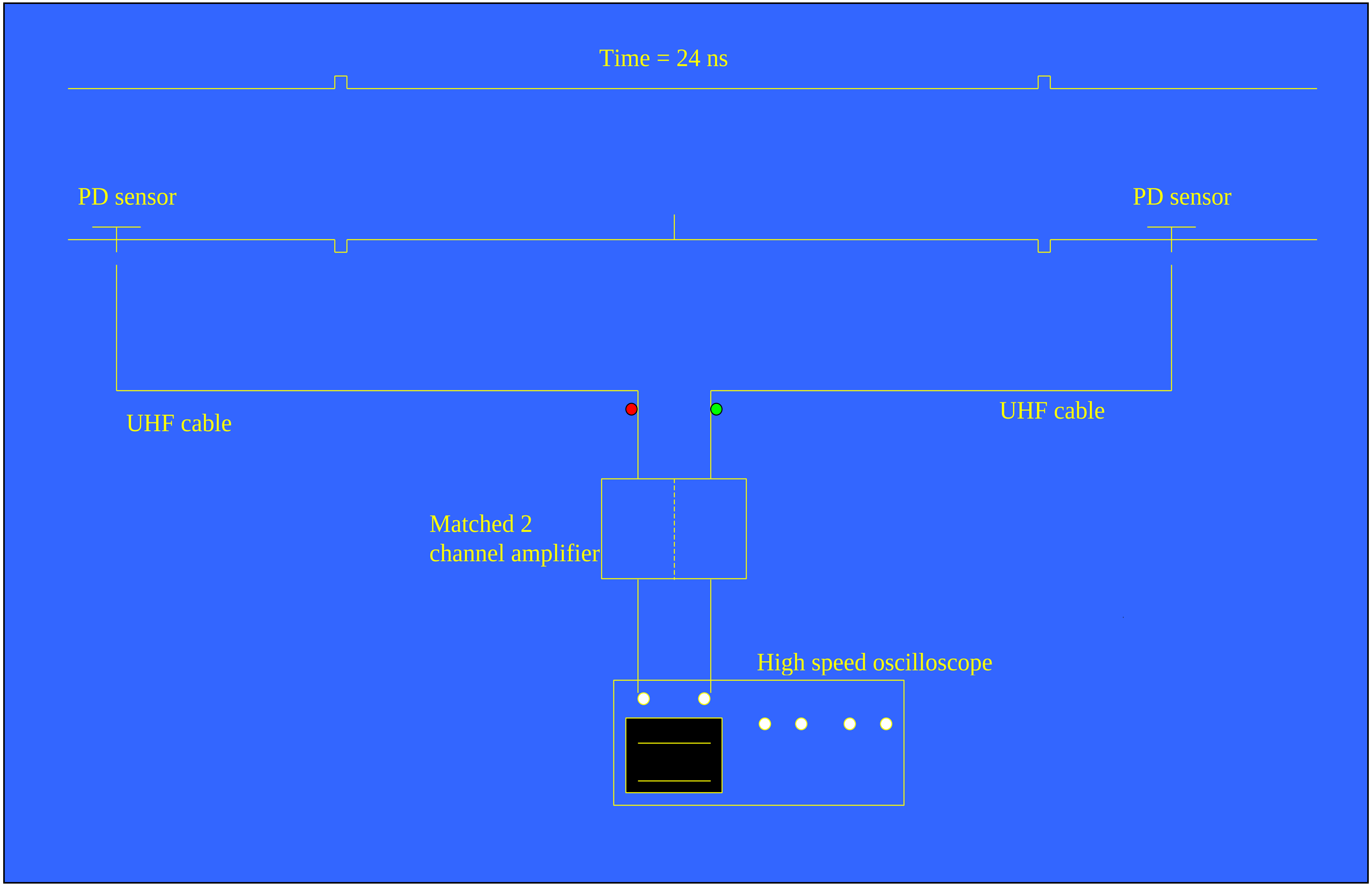

Time = 9 ns
PD sensor
PD sensor
UHF cable
UHF cable
Matched 2
channel amplifier
High speed oscilloscope

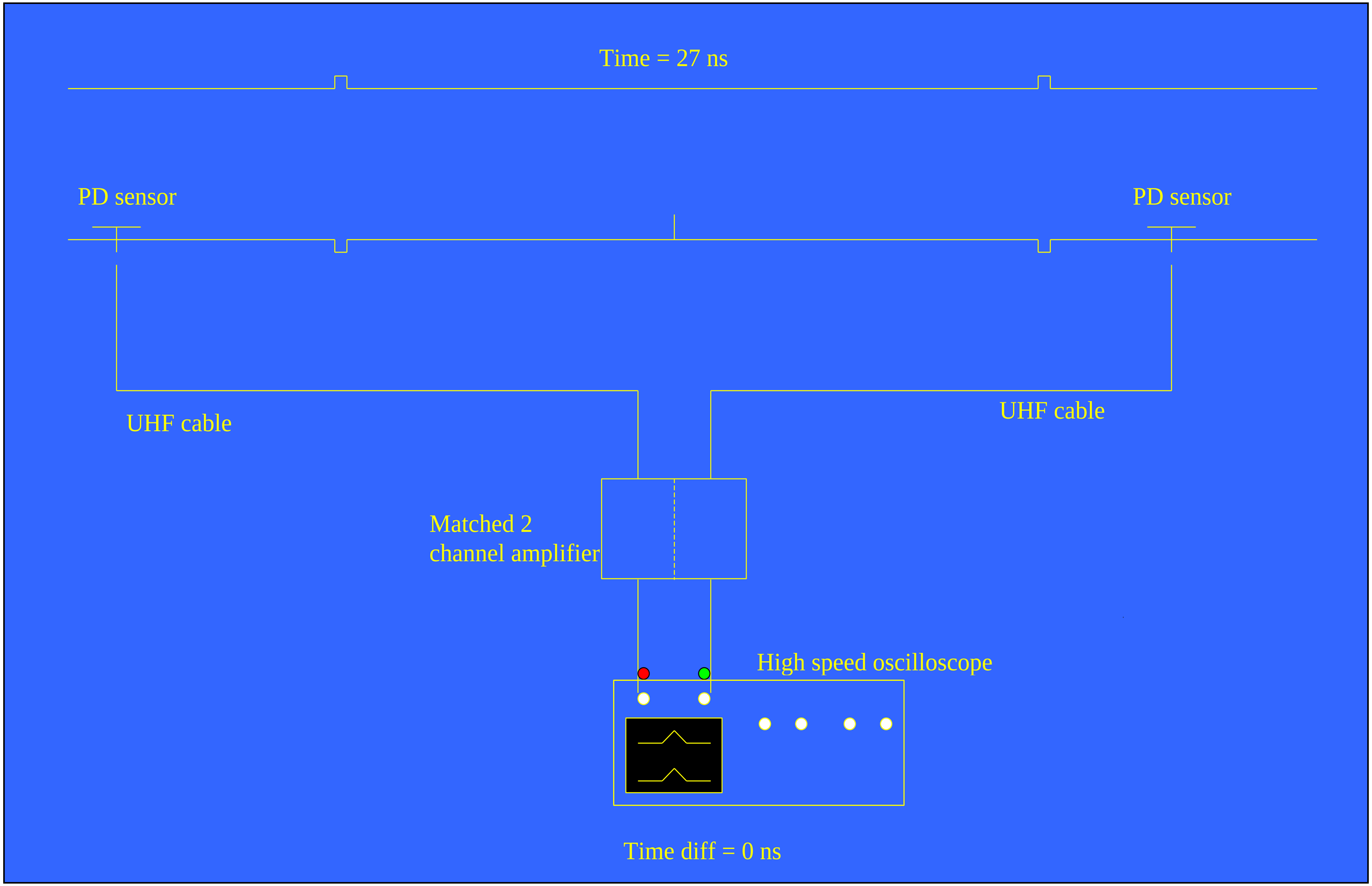

Time = 12 ns
PD sensor
PD sensor
UHF cable
UHF cable
Matched 2
channel amplifier
High speed oscilloscope


Time = 15 ns
PD sensor
PD sensor
UHF cable
UHF cable
Matched 2
channel amplifier
High speed oscilloscope


Time = 18 ns
PD sensor
PD sensor
UHF cable
UHF cable
Matched 2
channel amplifier
High speed oscilloscope


Time = 21 ns
PD sensor
PD sensor
UHF cable
UHF cable
Matched 2
channel amplifier
High speed oscilloscope


Time = 24 ns
PD sensor
PD sensor
UHF cable
UHF cable
Matched 2
channel amplifier
High speed oscilloscope


Time = 27 ns
PD sensor
PD sensor
UHF cable
UHF cable
Matched 2
channel amplifier
High speed oscilloscope
Time diff = 0 ns

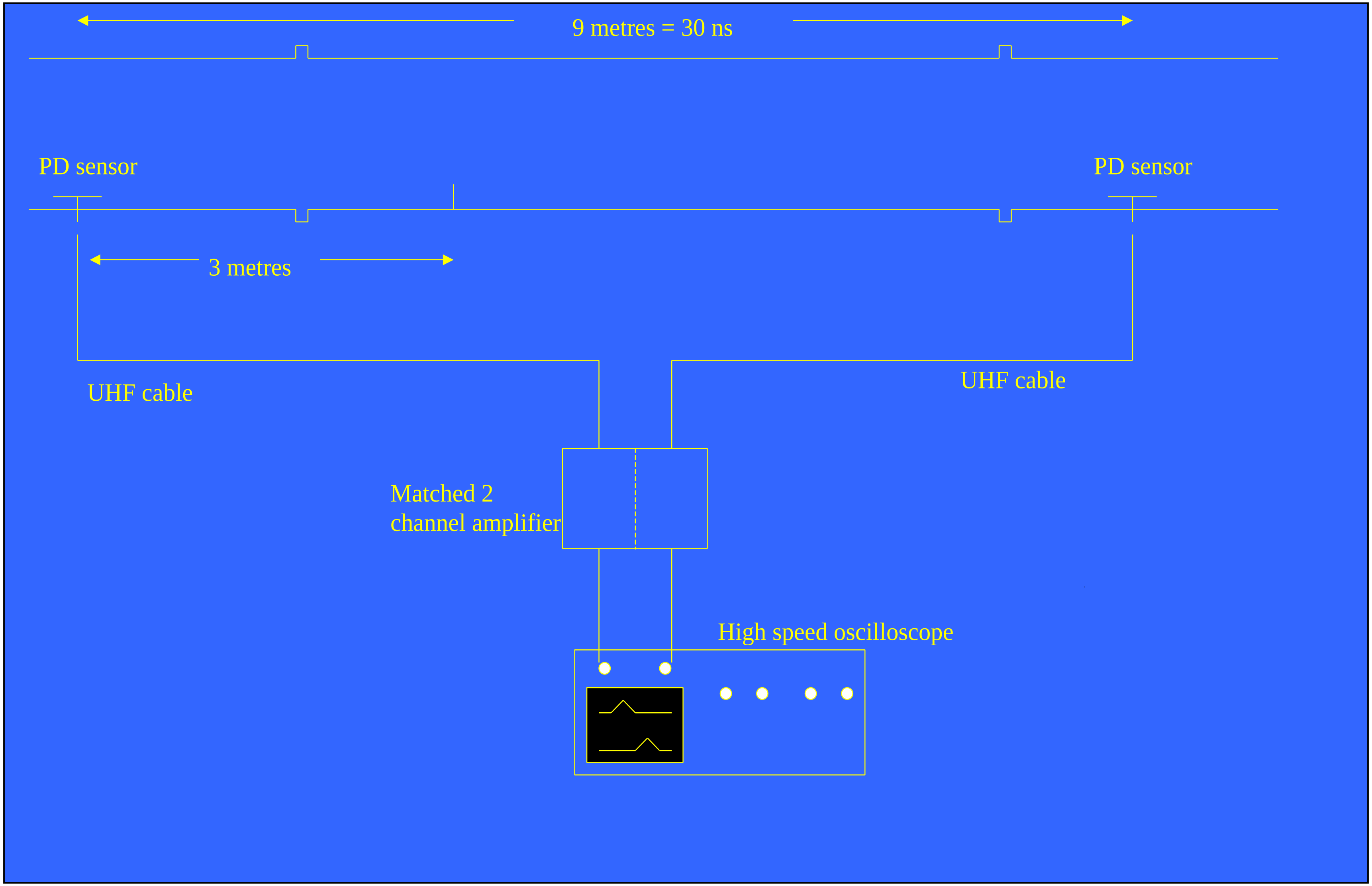
Time difference = 0 ns

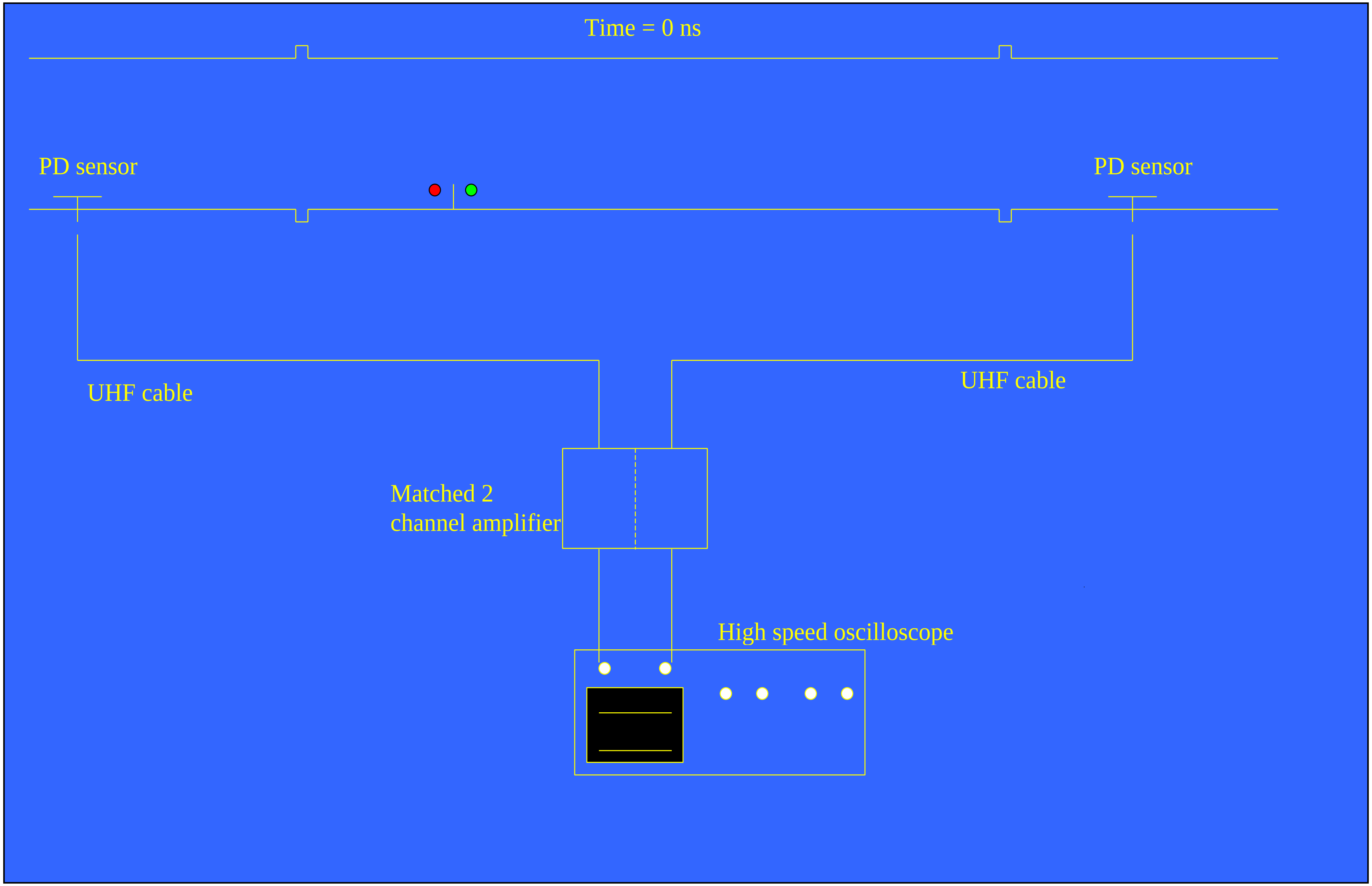
$$d = (D-0.3t) / 2$$

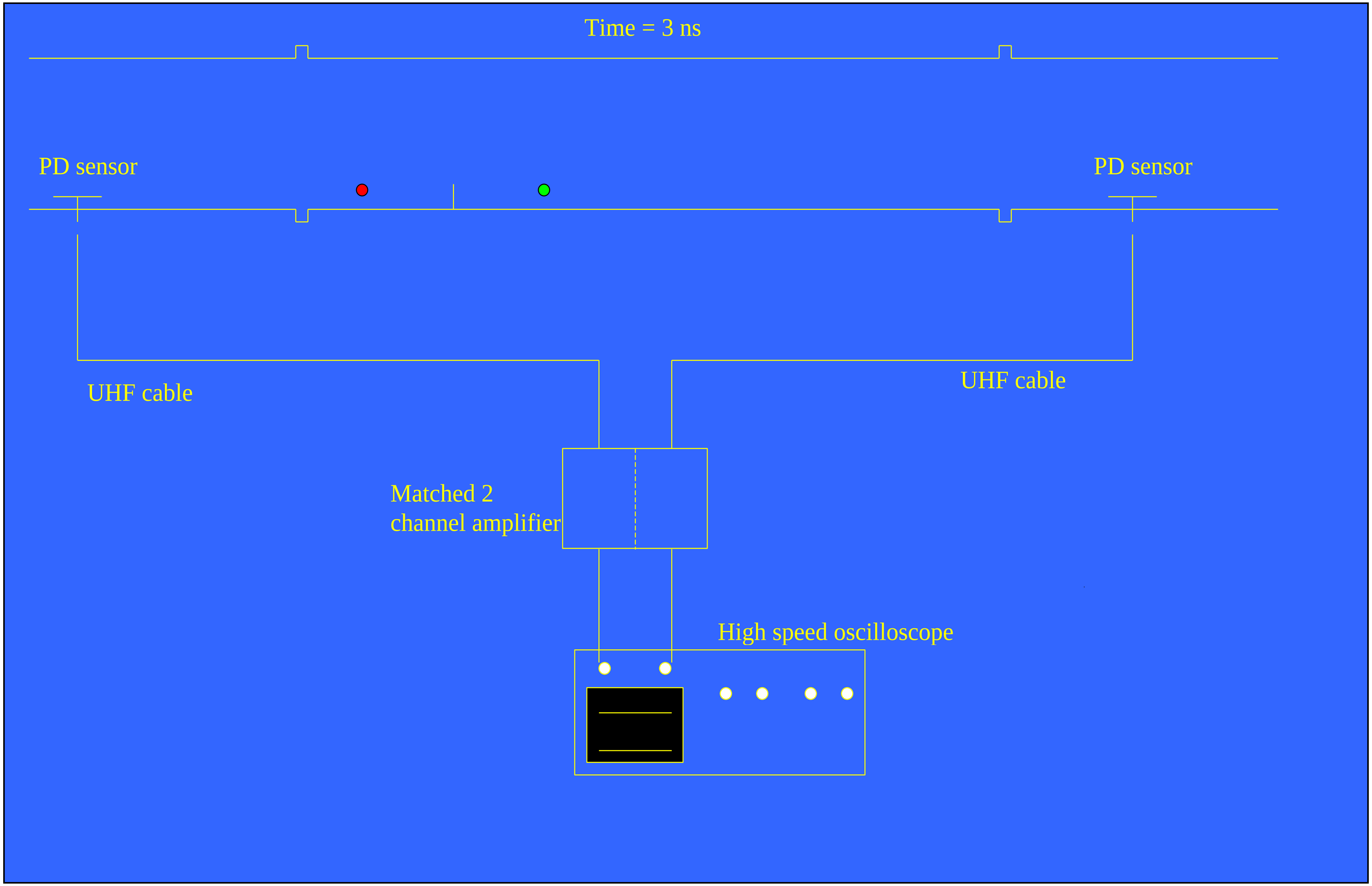
where D is the distance between couplers (following path of the busbar)
t is the time difference in nanoseconds
d is the distance from the first coupler

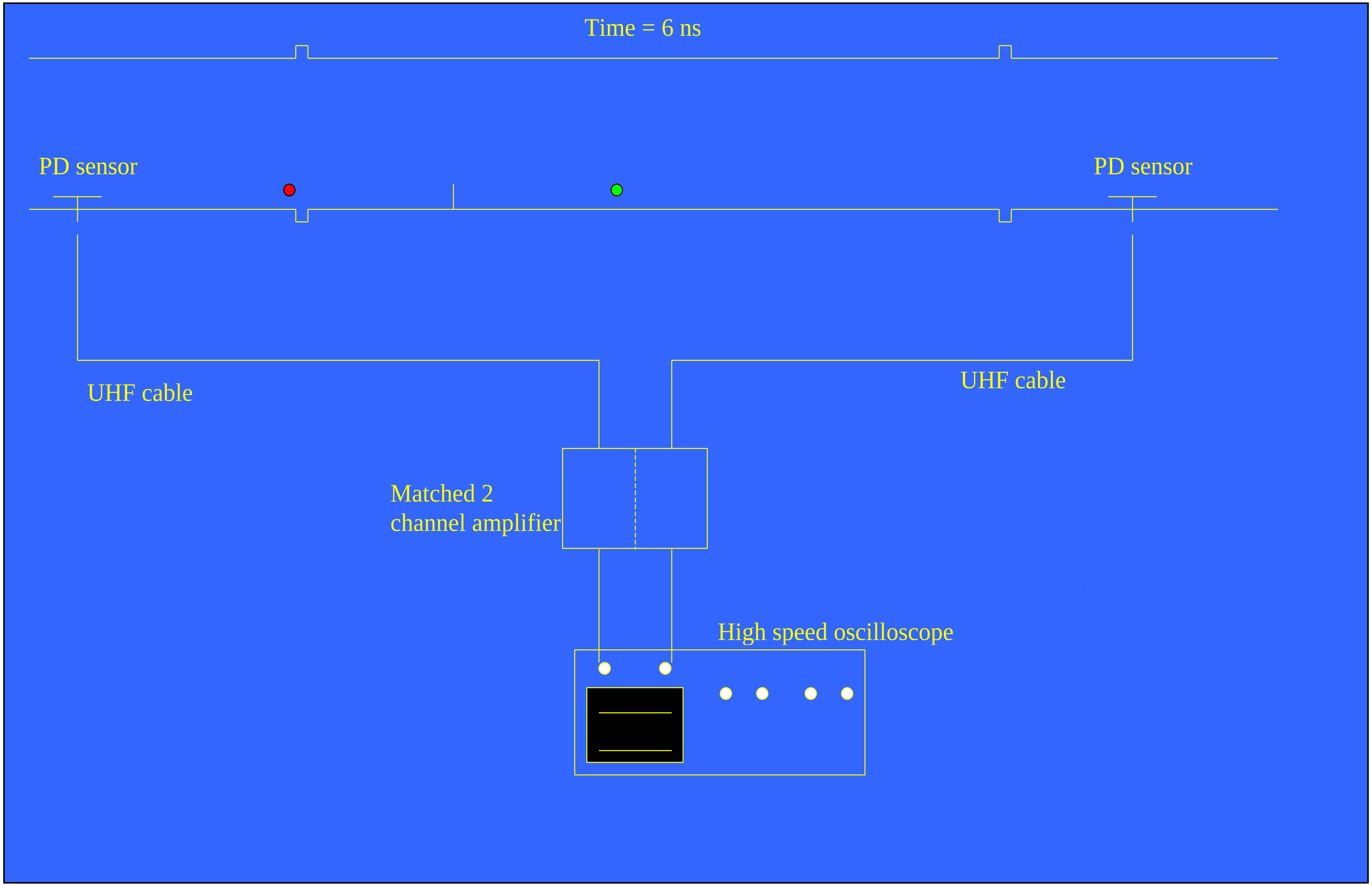
This gives a value of:

$$d = 4.5\text{m}$$

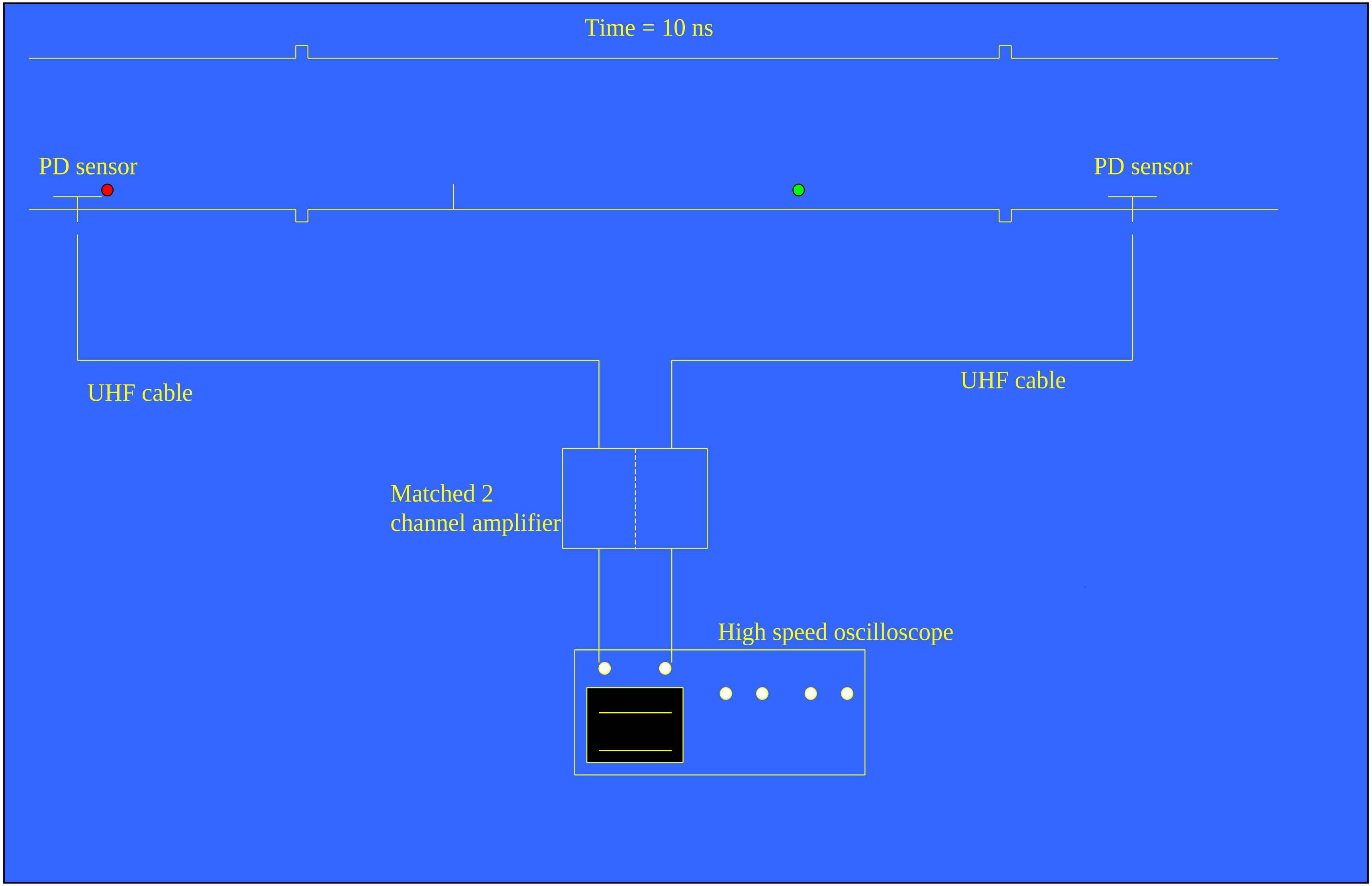

9 metres = 30 ns
PD sensor
PD sensor
3 metres
UHF cable
UHF cable
Matched 2
channel amplifier
High speed oscilloscope

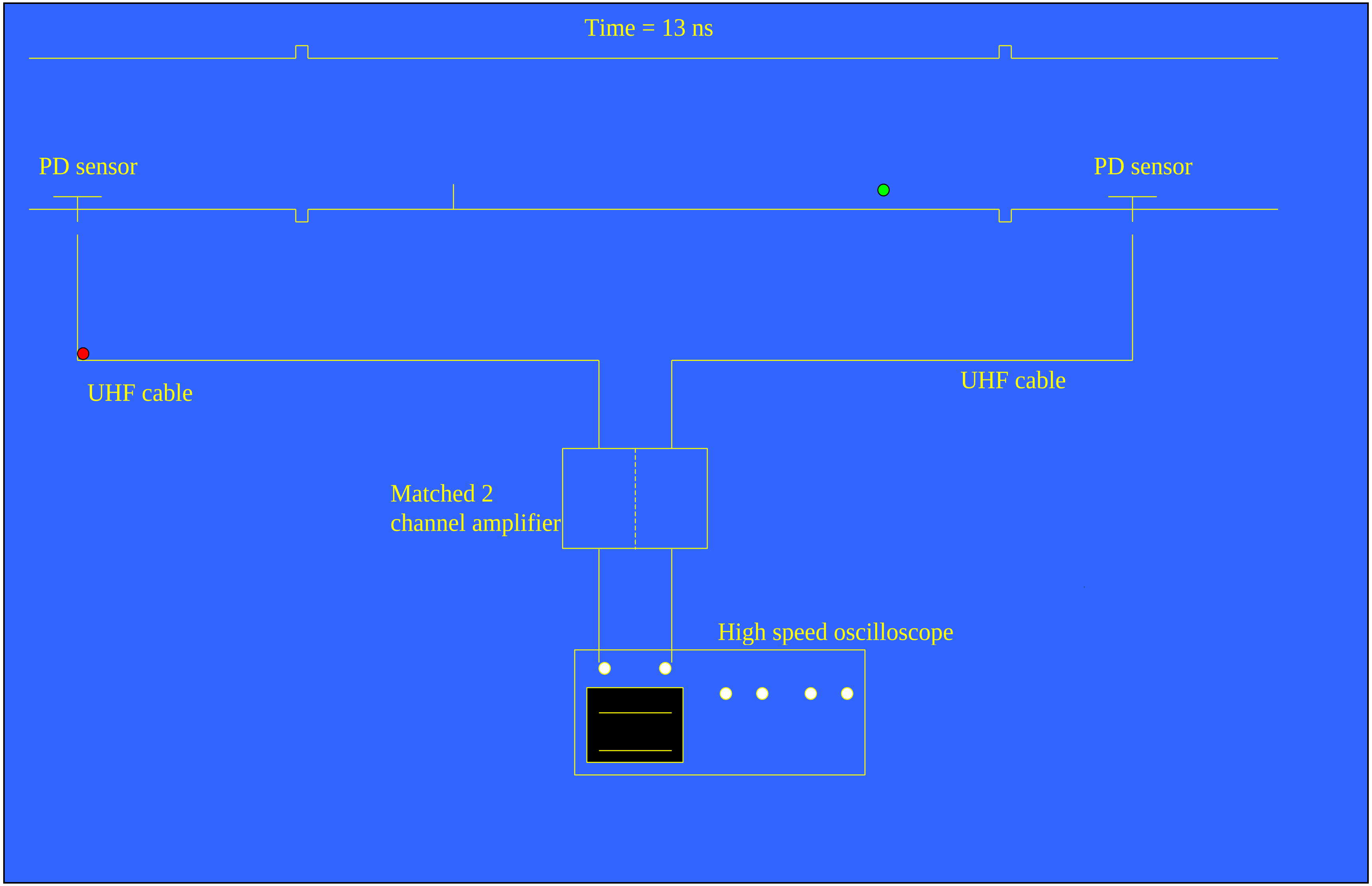

Time = 0 ns
PD sensor
PD sensor
UHF cable
UHF cable
Matched 2
channel amplifier
High speed oscilloscope

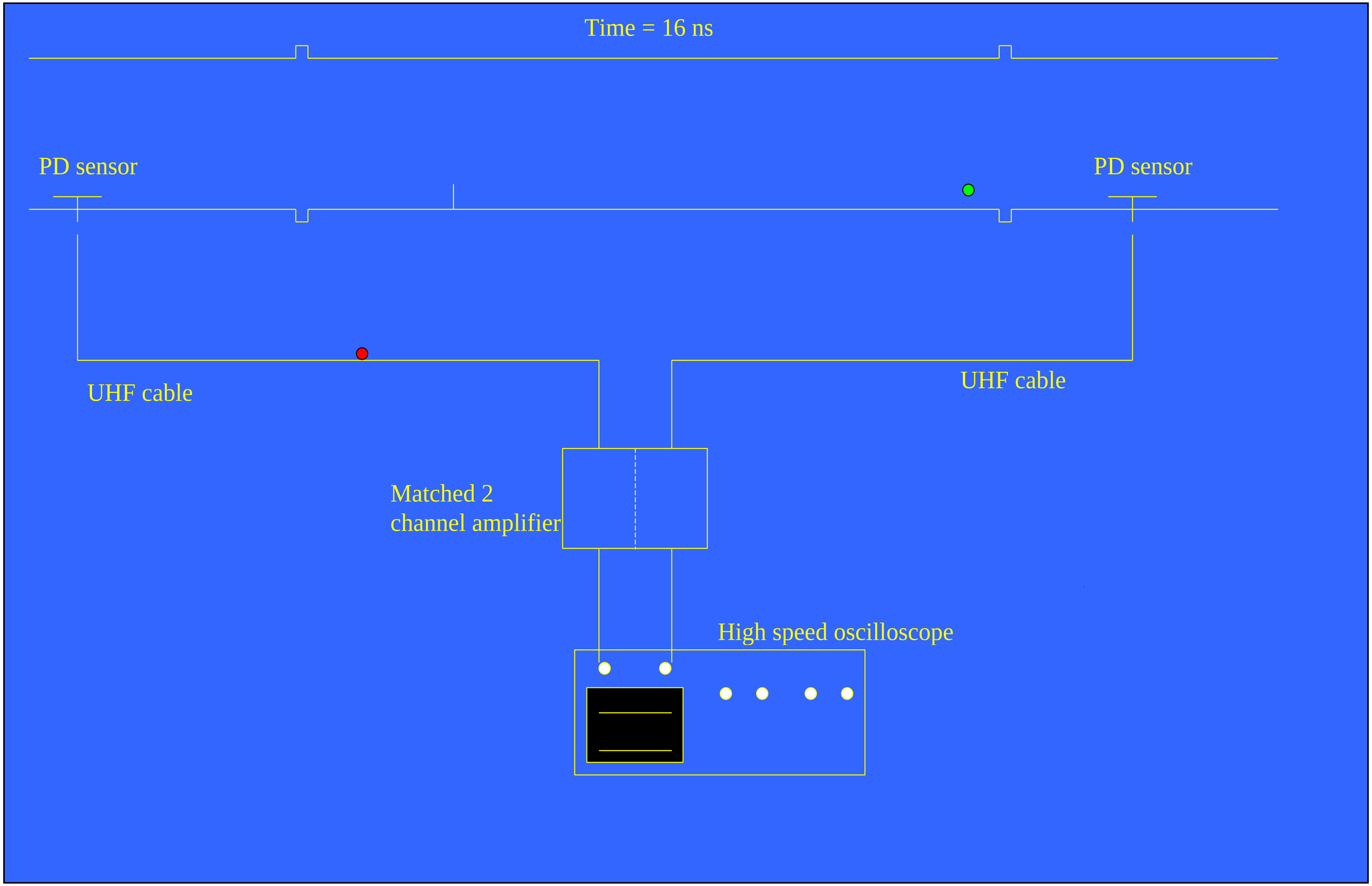

Time = 3 ns
PD sensor
PD sensor
UHF cable
UHF cable
Matched 2
channel amplifier
High speed oscilloscope



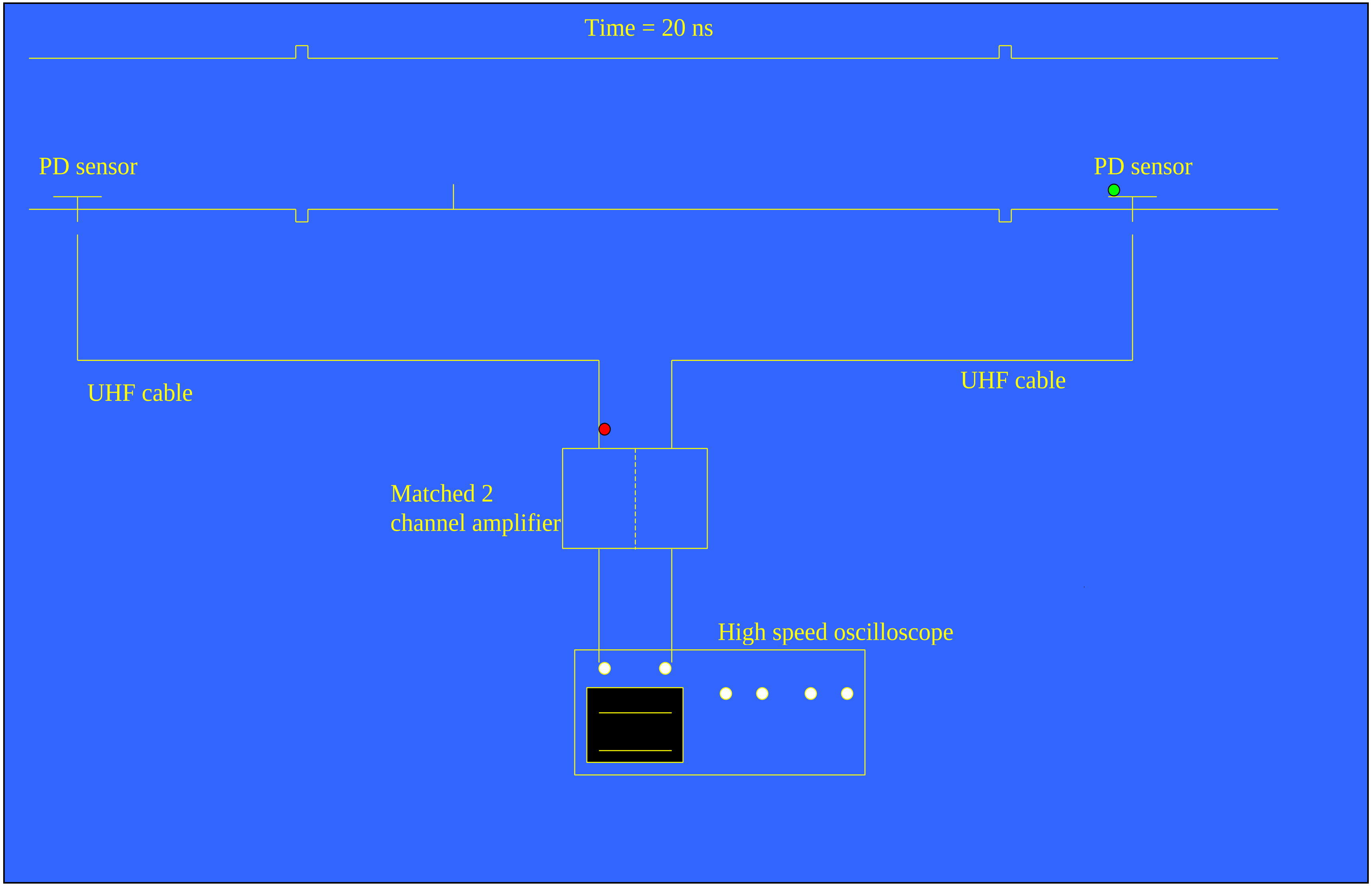
Time = 6 ns
PD sensor
PD sensor
UHF cable
UHF cable
Matched 2
channel amplifier
High speed oscilloscope

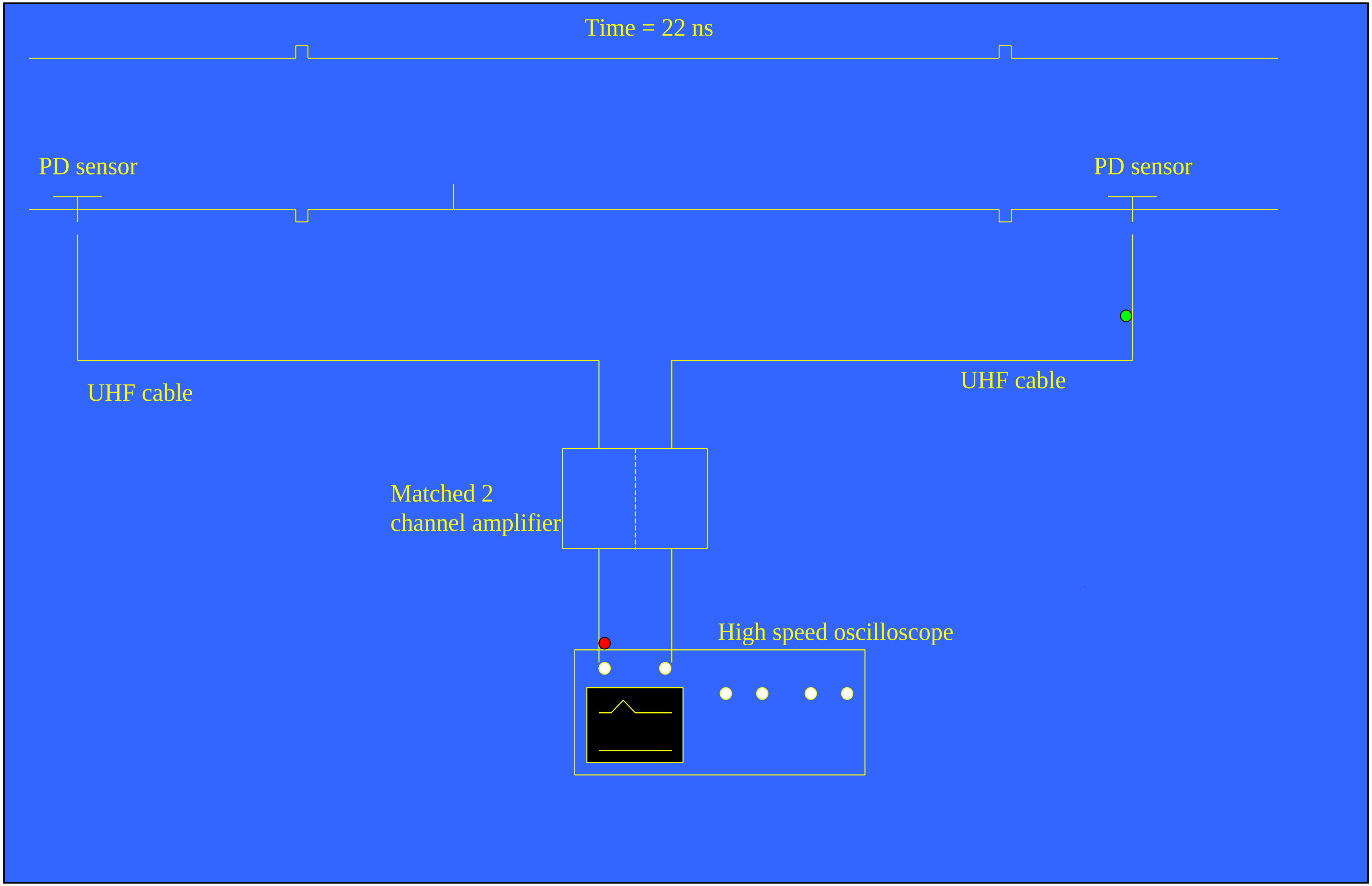

Time = 10 ns
PD sensor
PD sensor
UHF cable
UHF cable
Matched 2
channel amplifier
High speed oscilloscope

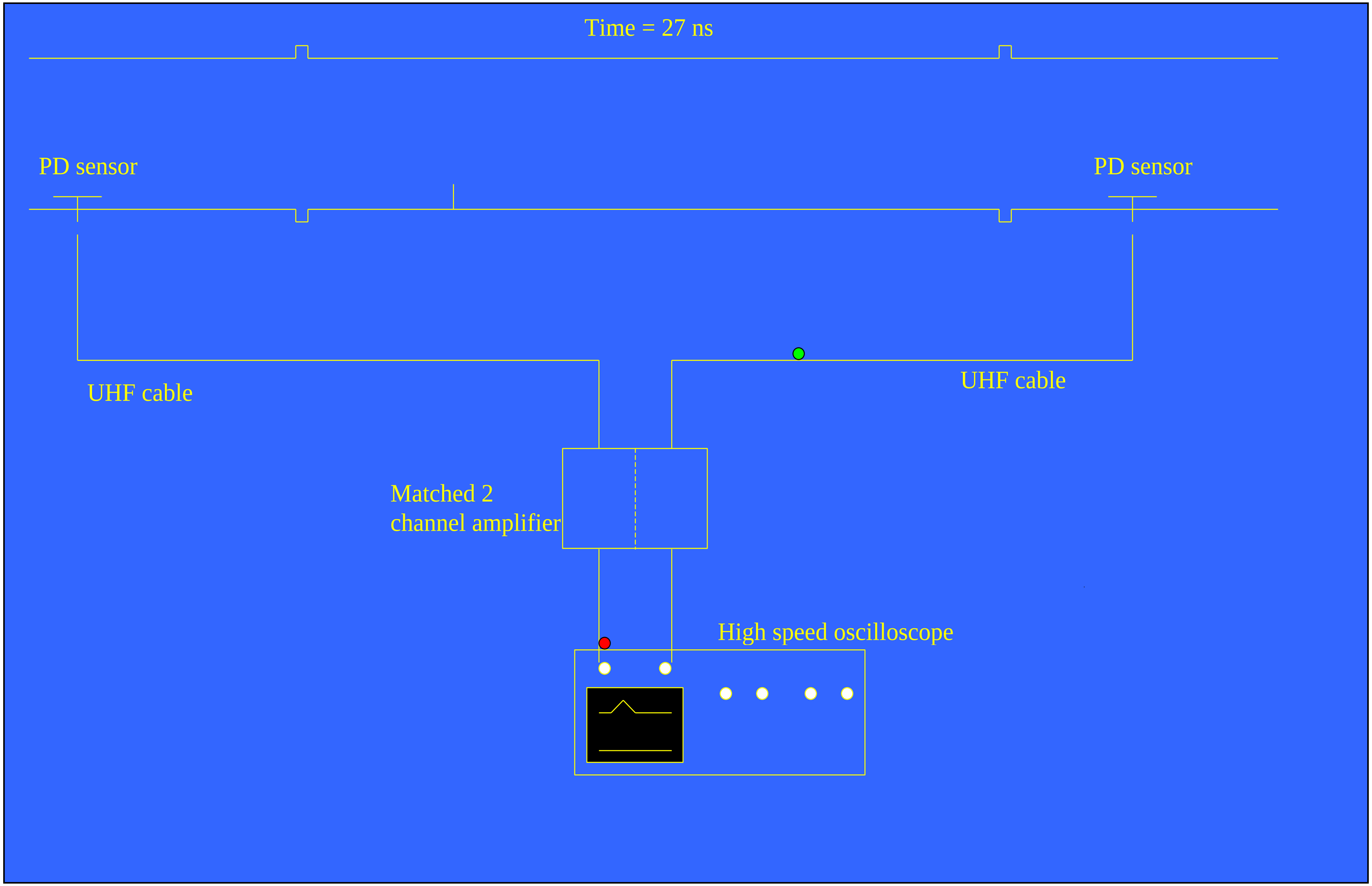

Time = 13 ns
PD sensor
PD sensor
UHF cable
UHF cable
Matched 2
channel amplifier
High speed oscilloscope

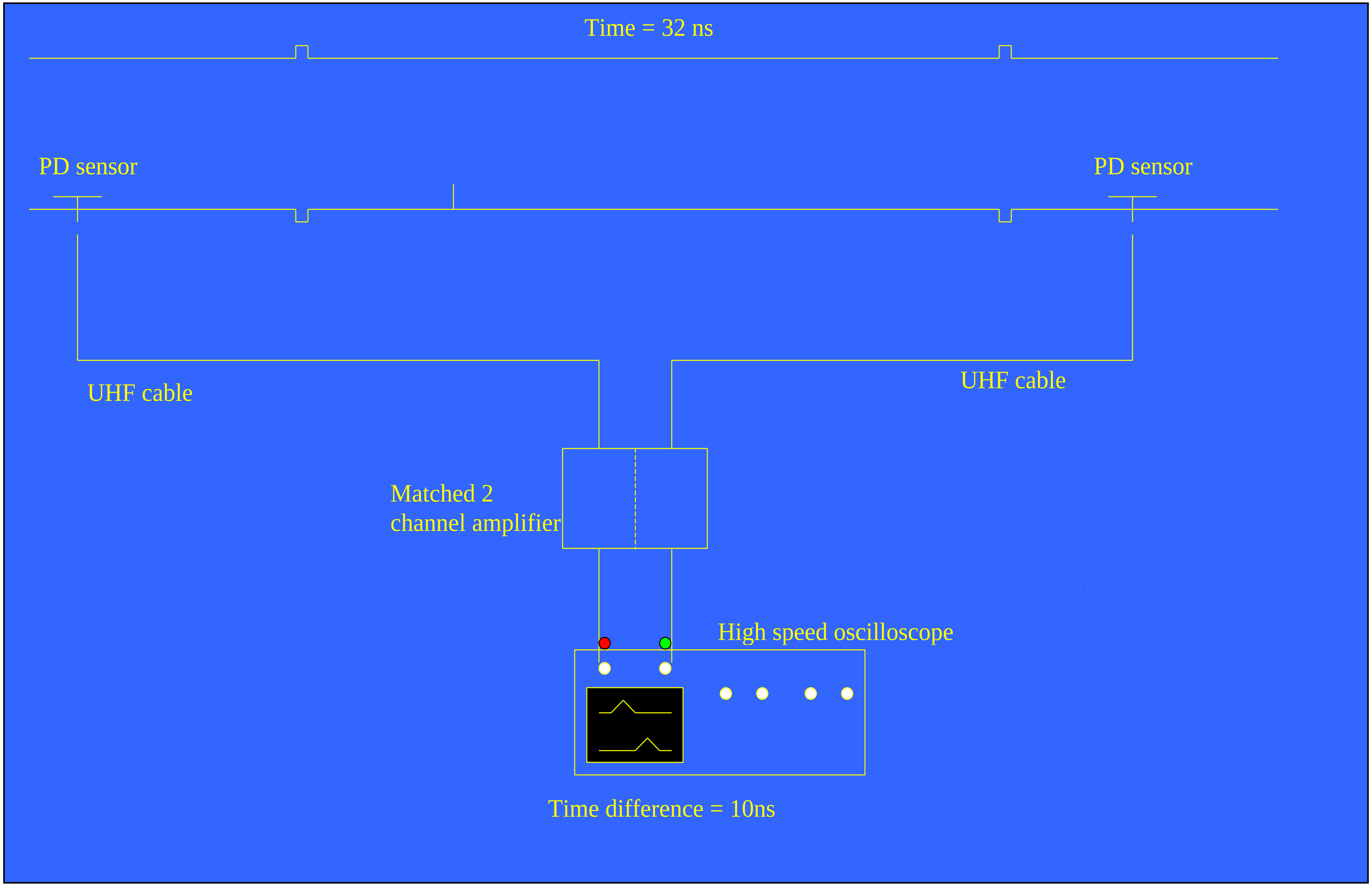


Time = 16 ns
PD sensor
PD sensor
UHF cable
UHF cable
Matched 2
channel amplifier
High speed oscilloscope


Time = 20 ns
PD sensor
PD sensor
UHF cable
UHF cable
Matched 2
channel amplifier
High speed oscilloscope


Time = 22 ns
PD sensor
PD sensor
UHF cable
UHF cable
Matched 2
channel amplifier
High speed oscilloscope


Time = 27 ns
PD sensor
PD sensor
UHF cable
UHF cable
Matched 2
channel amplifier
High speed oscilloscope


Time = 32 ns
PD sensor
PD sensor
UHF cable
UHF cable
Matched 2
channel amplifier
High speed oscilloscope
Time difference = 10ns

Time difference = 10 ns

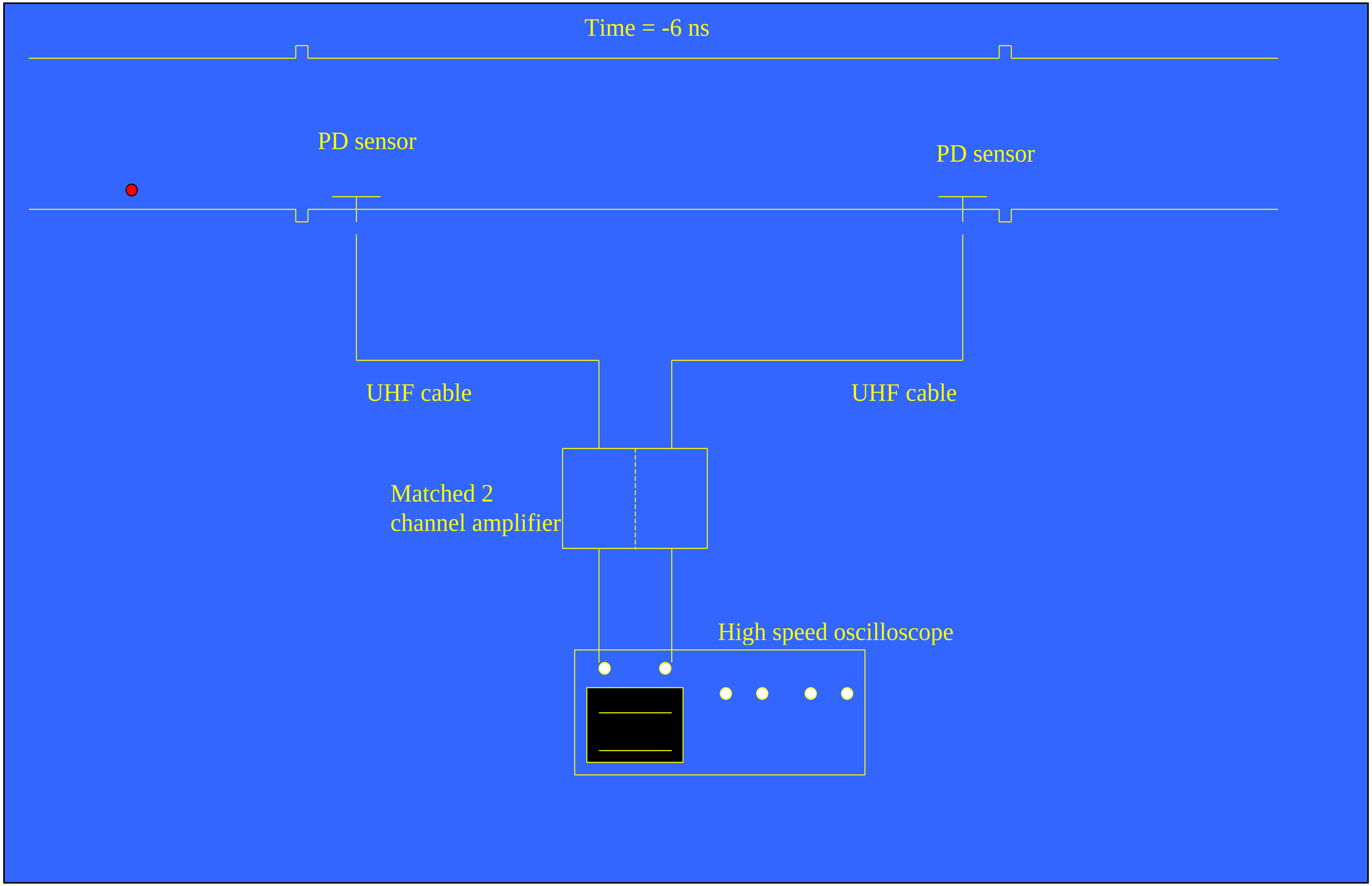
$$d = (D-0.3t) / 2$$

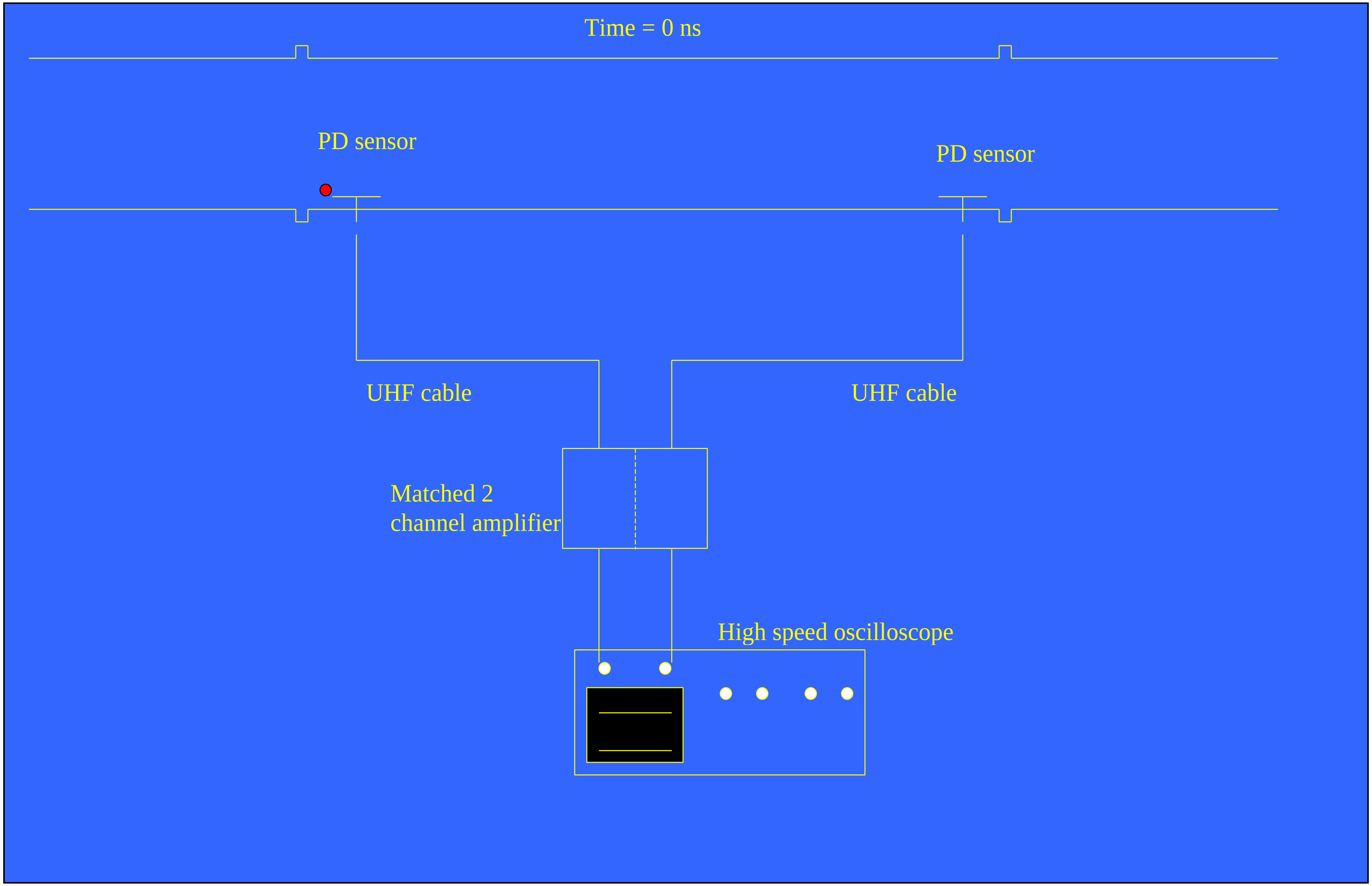
where D is the distance between couplers (following path of the busbar)
t is the time difference in nanoseconds
d is the distance from the first coupler

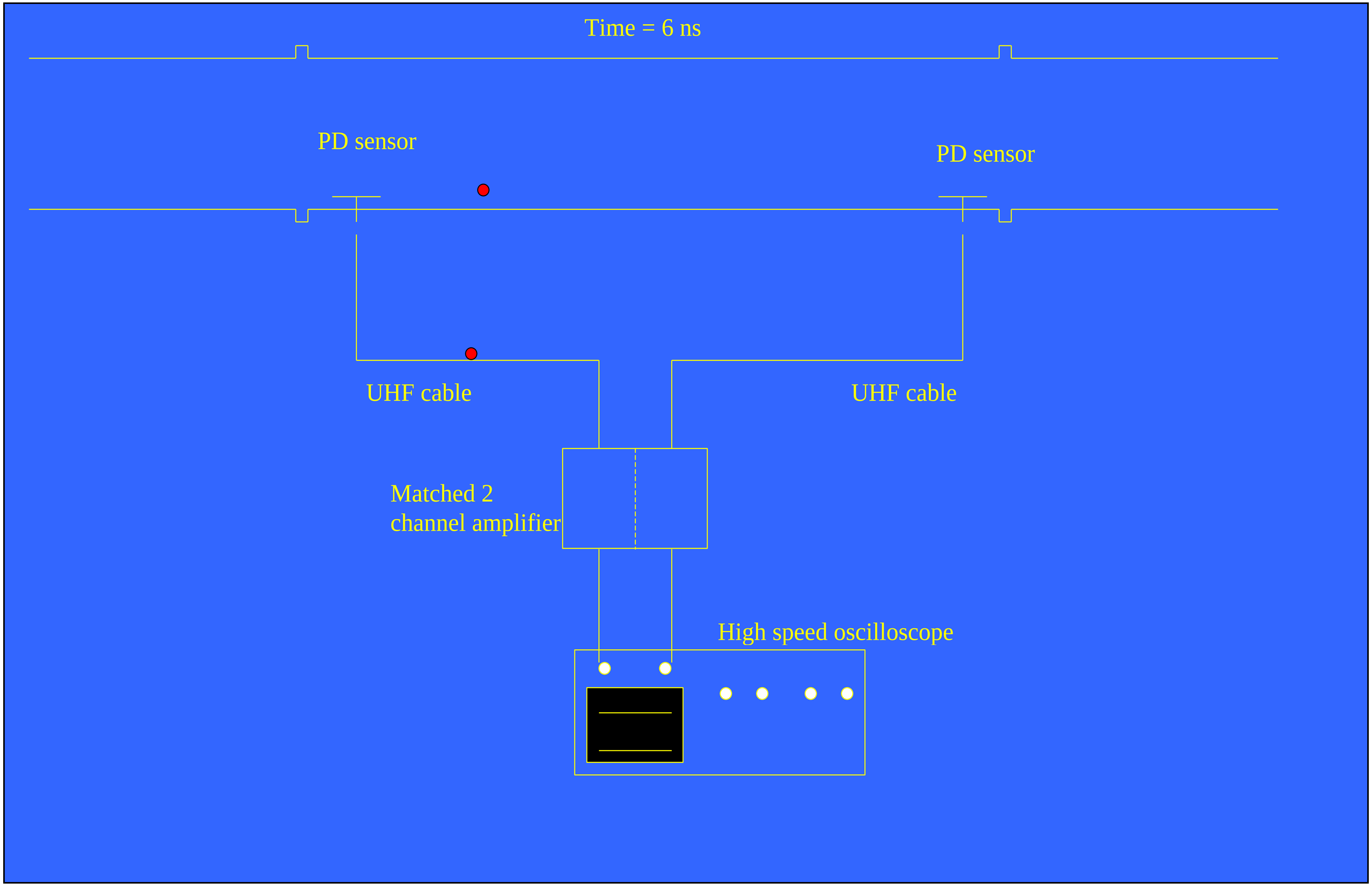
This gives a value of:

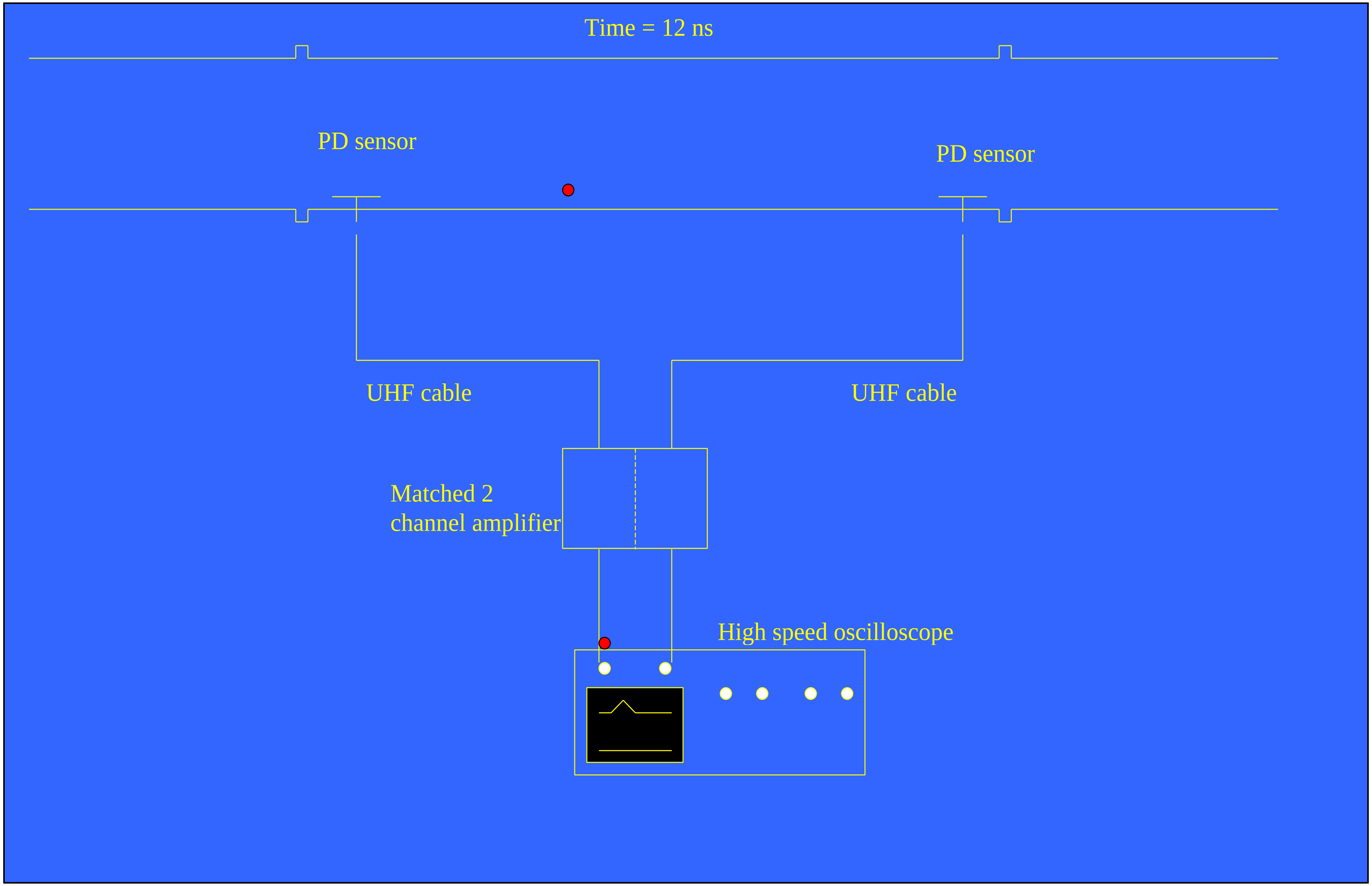
d = 3m (from red/first coupler)

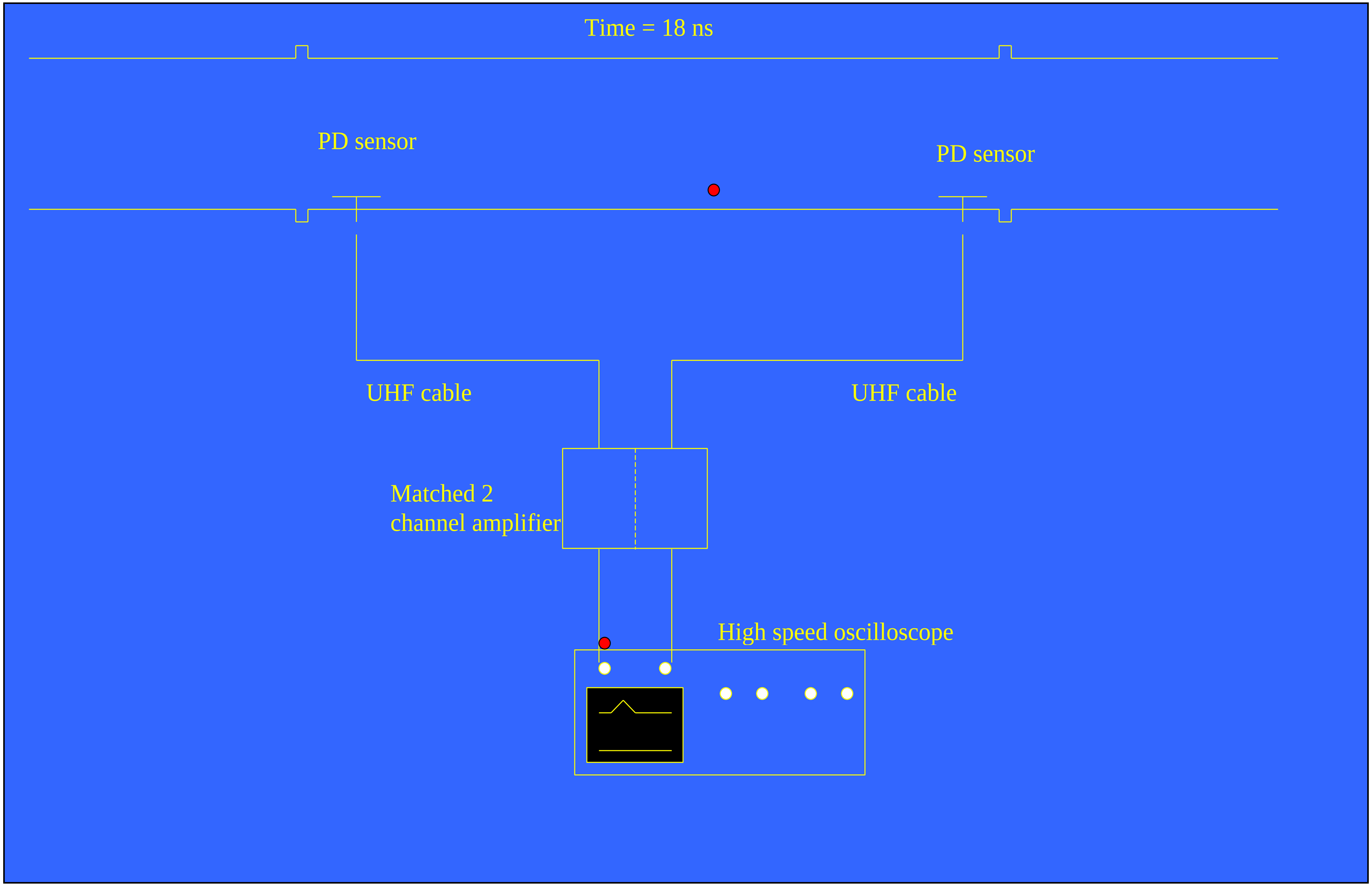
Defects outside of the coupler

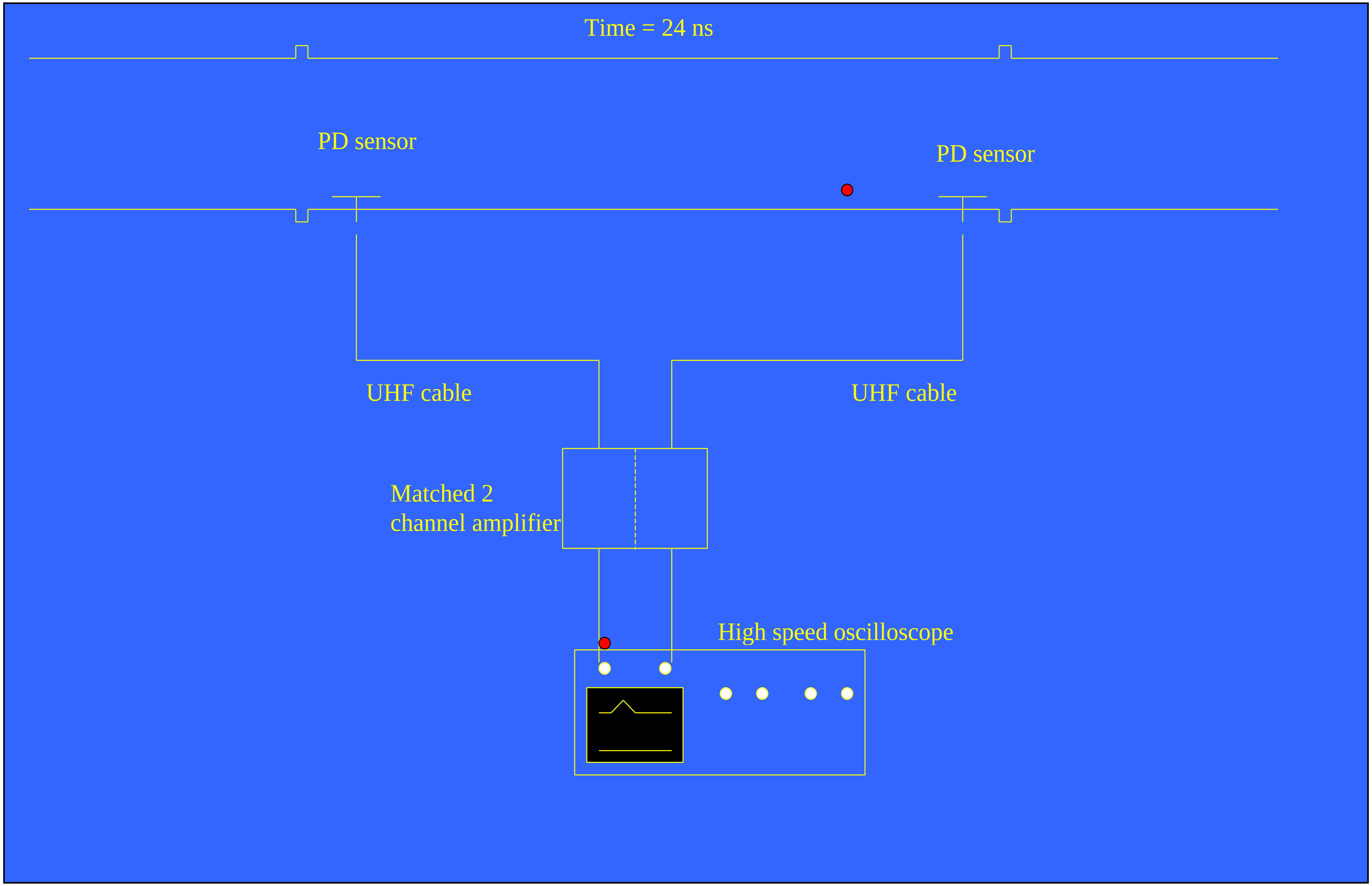

Time = -6 ns
PD sensor
PD sensor
UHF cable
UHF cable
Matched 2
channel amplifier
High speed oscilloscope


Time = 0 ns
PD sensor
PD sensor
UHF cable
UHF cable
Matched 2
channel amplifier
High speed oscilloscope

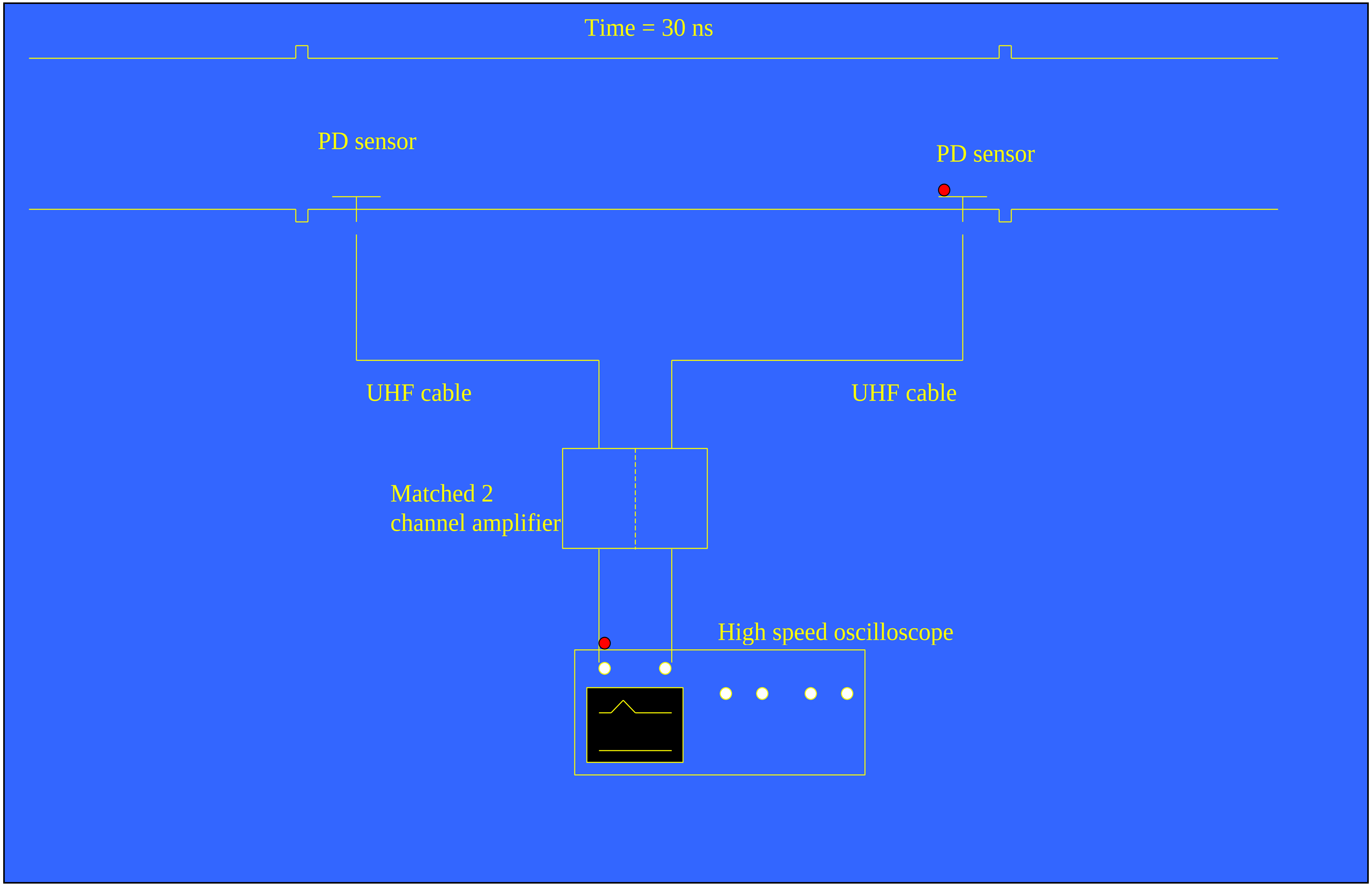

Time = 6 ns
PD sensor
PD sensor
UHF cable
UHF cable
Matched 2
channel amplifier
High speed oscilloscope

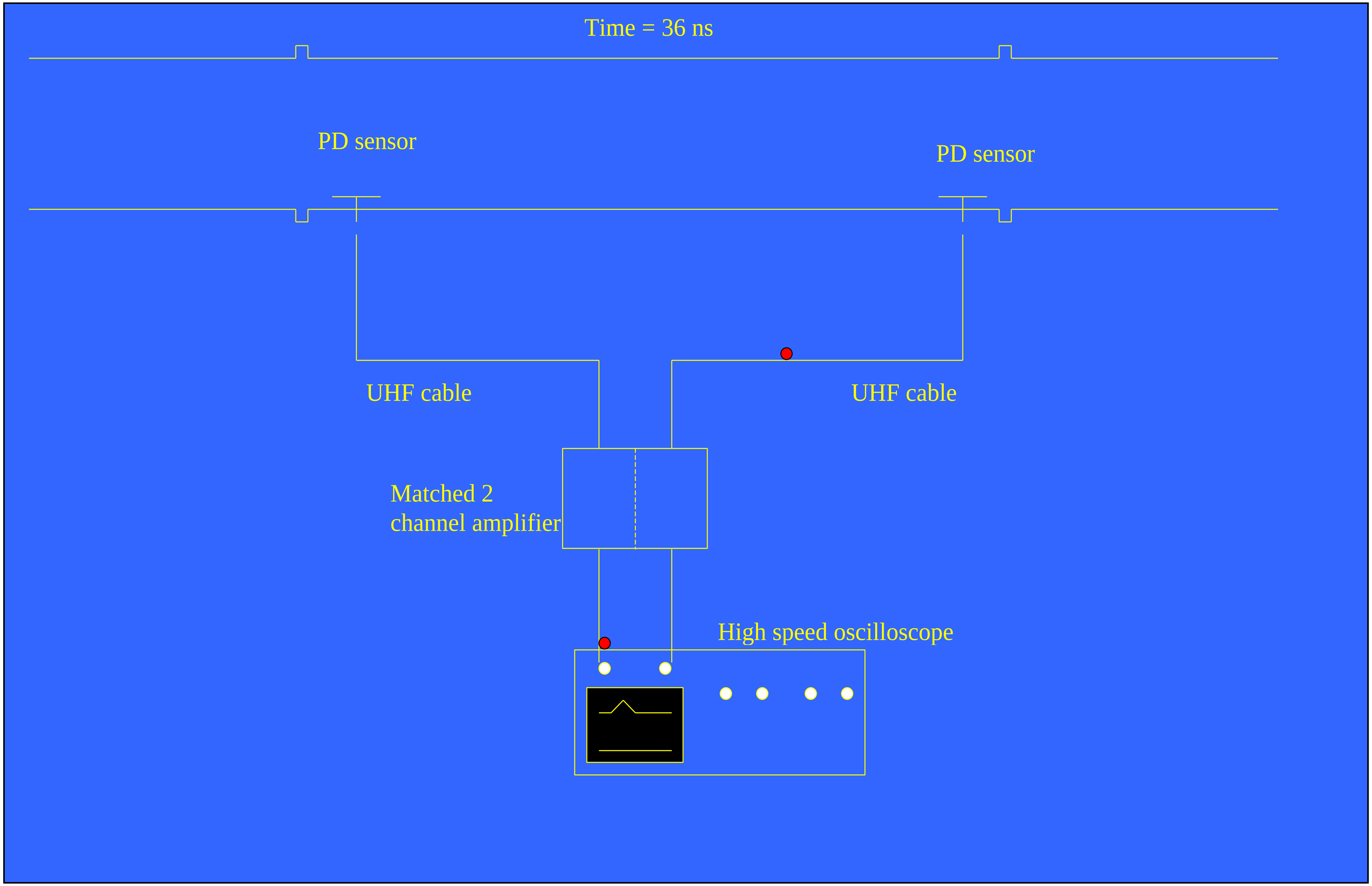

Time = 12 ns
PD sensor
PD sensor
UHF cable
UHF cable
Matched 2
channel amplifier
High speed oscilloscope

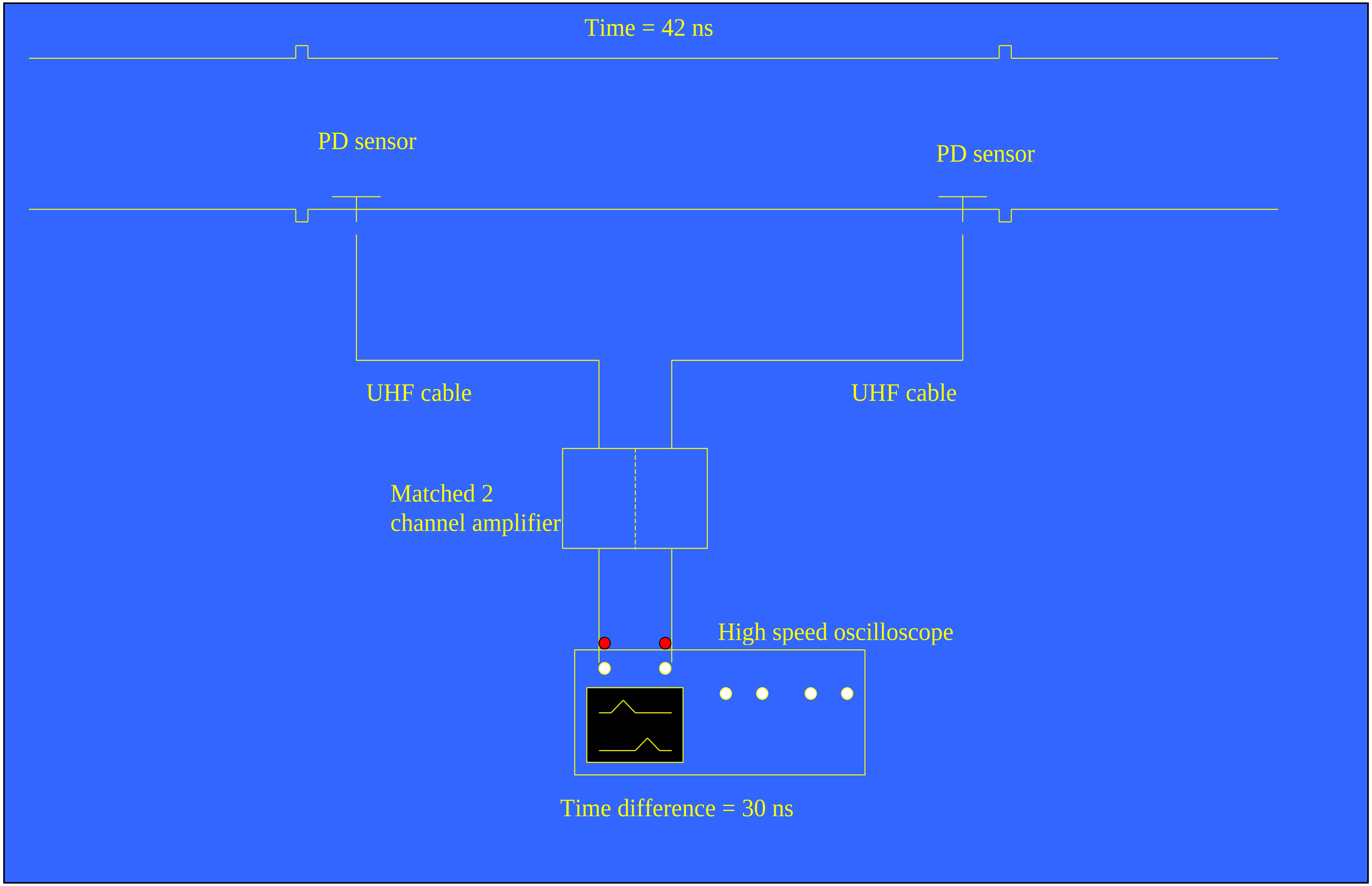

Time = 18 ns
PD sensor
PD sensor
UHF cable
UHF cable
Matched 2
channel amplifier
High speed oscilloscope



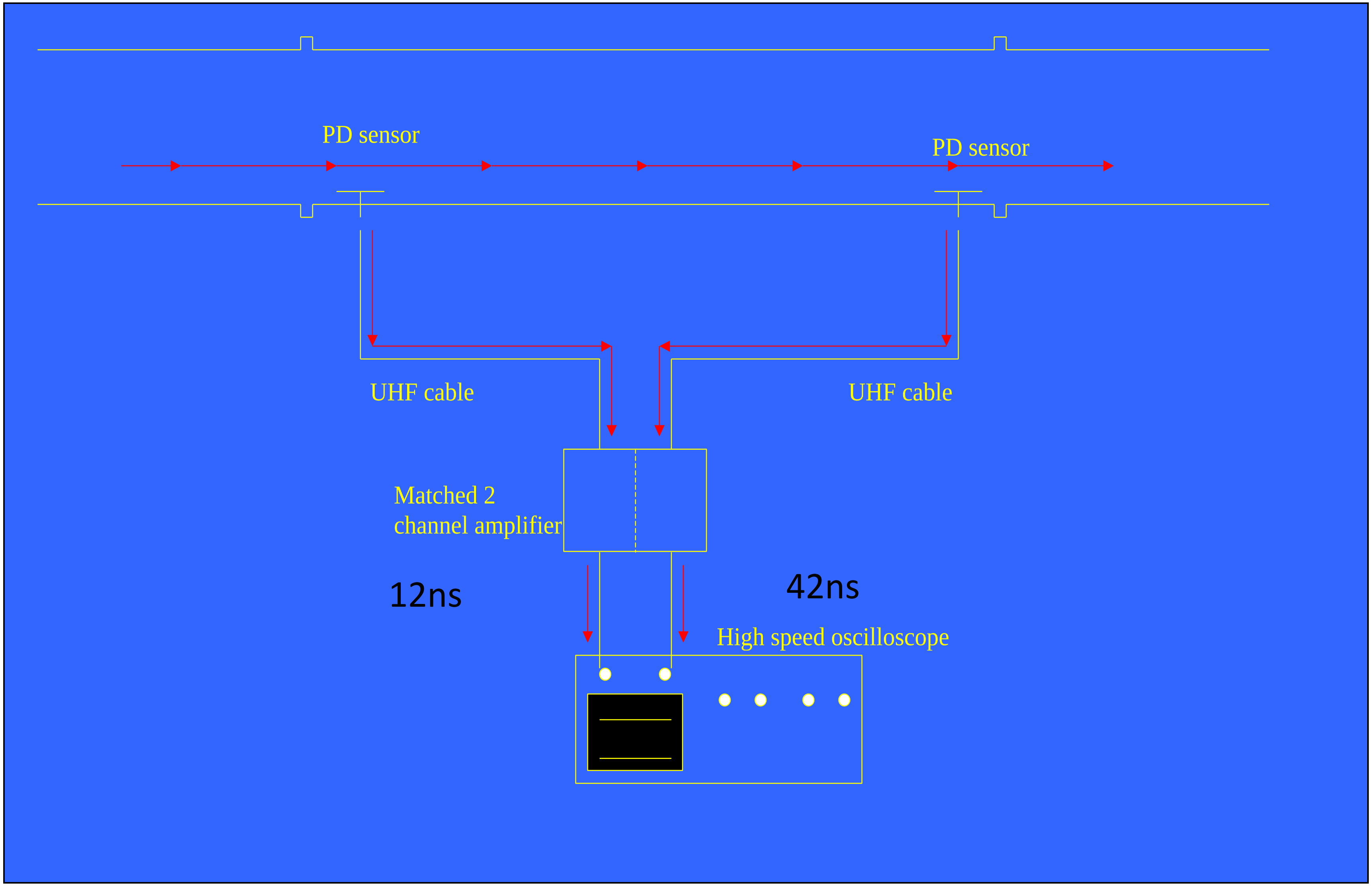
Time = 24 ns
PD sensor
PD sensor
UHF cable
UHF cable
Matched 2
channel amplifier
High speed oscilloscope


Time = 30 ns
PD sensor
PD sensor
UHF cable
UHF cable
Matched 2
channel amplifier
High speed oscilloscope


Time = 36 ns
PD sensor
PD sensor
UHF cable
UHF cable
Matched 2
channel amplifier
High speed oscilloscope



Time = 42 ns
PD sensor
PD sensor
UHF cable
UHF cable
Matched 2
channel amplifier
High speed oscilloscope
Time difference = 30 ns


PD sensor
PD sensor
UHF cable
UHF cable
Matched 2
channel amplifier
12ns
42ns
High speed oscilloscope

Time difference = 30 ns

$$d = (D-0.3t) / 2$$

where D is the distance between couplers (following path of the busbar)
t is the time difference in nanoseconds
d is the distance from the first coupler

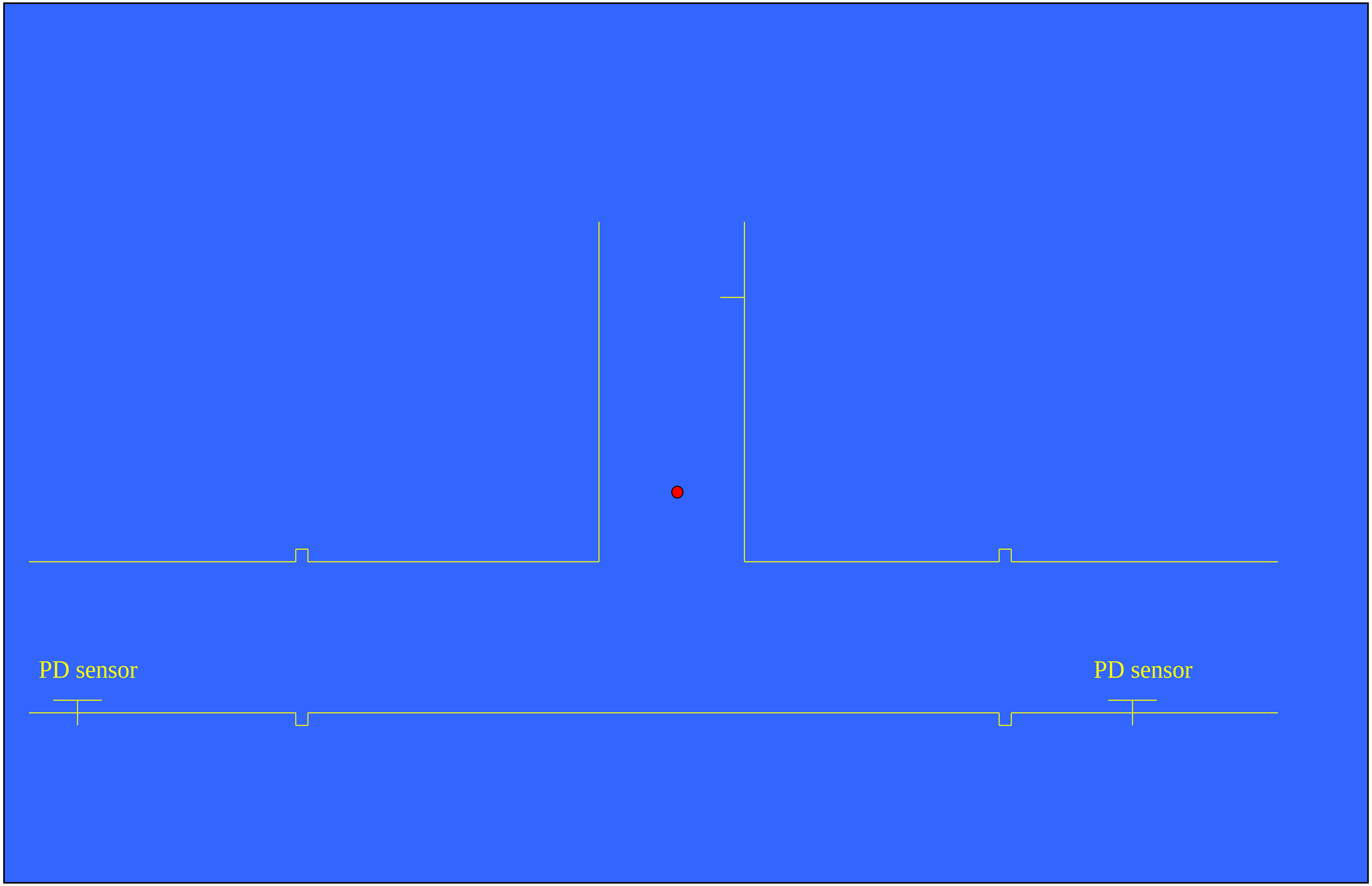
This gives a value of:

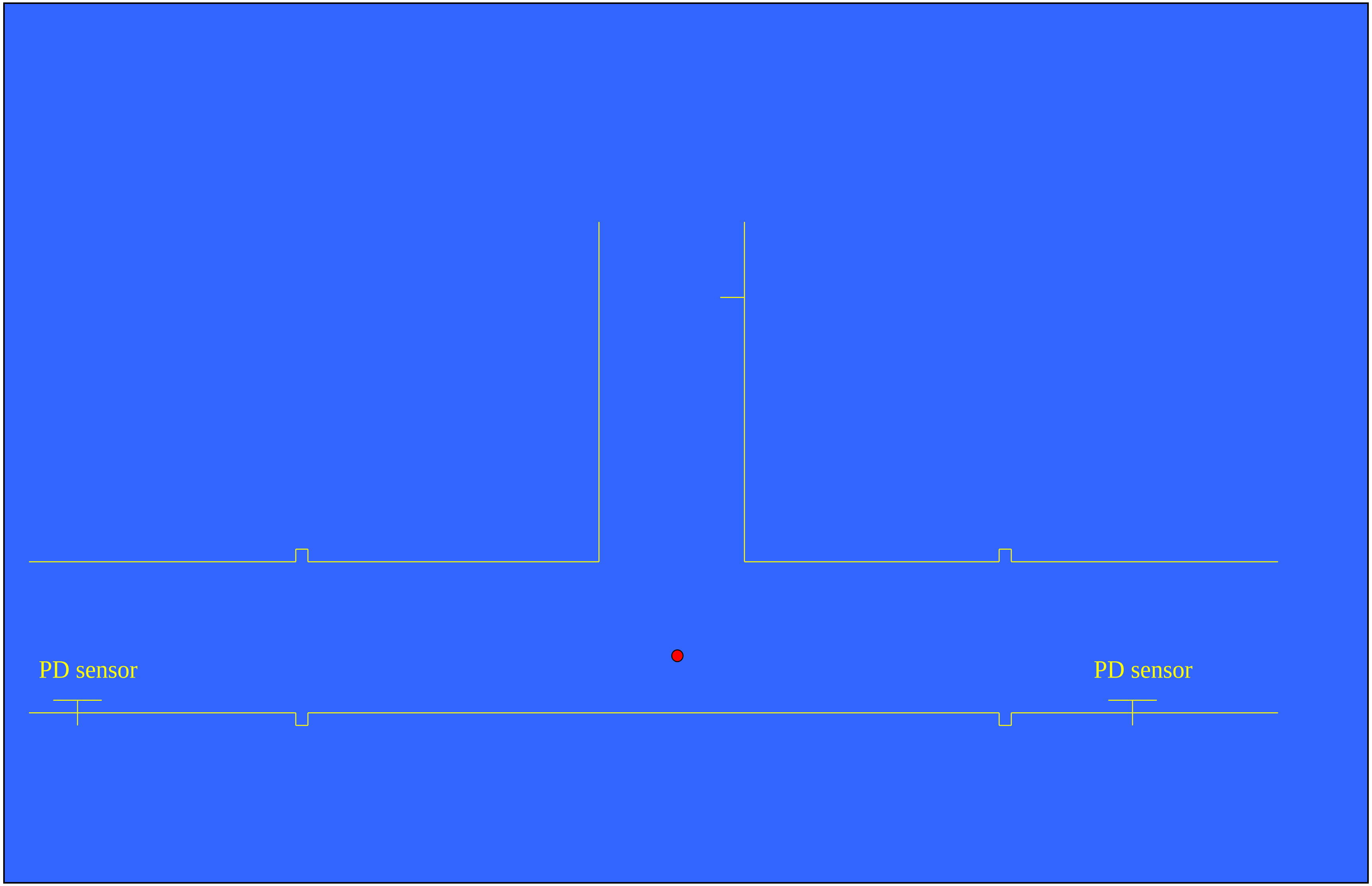
$d = 0m$ (from red/first coupler)

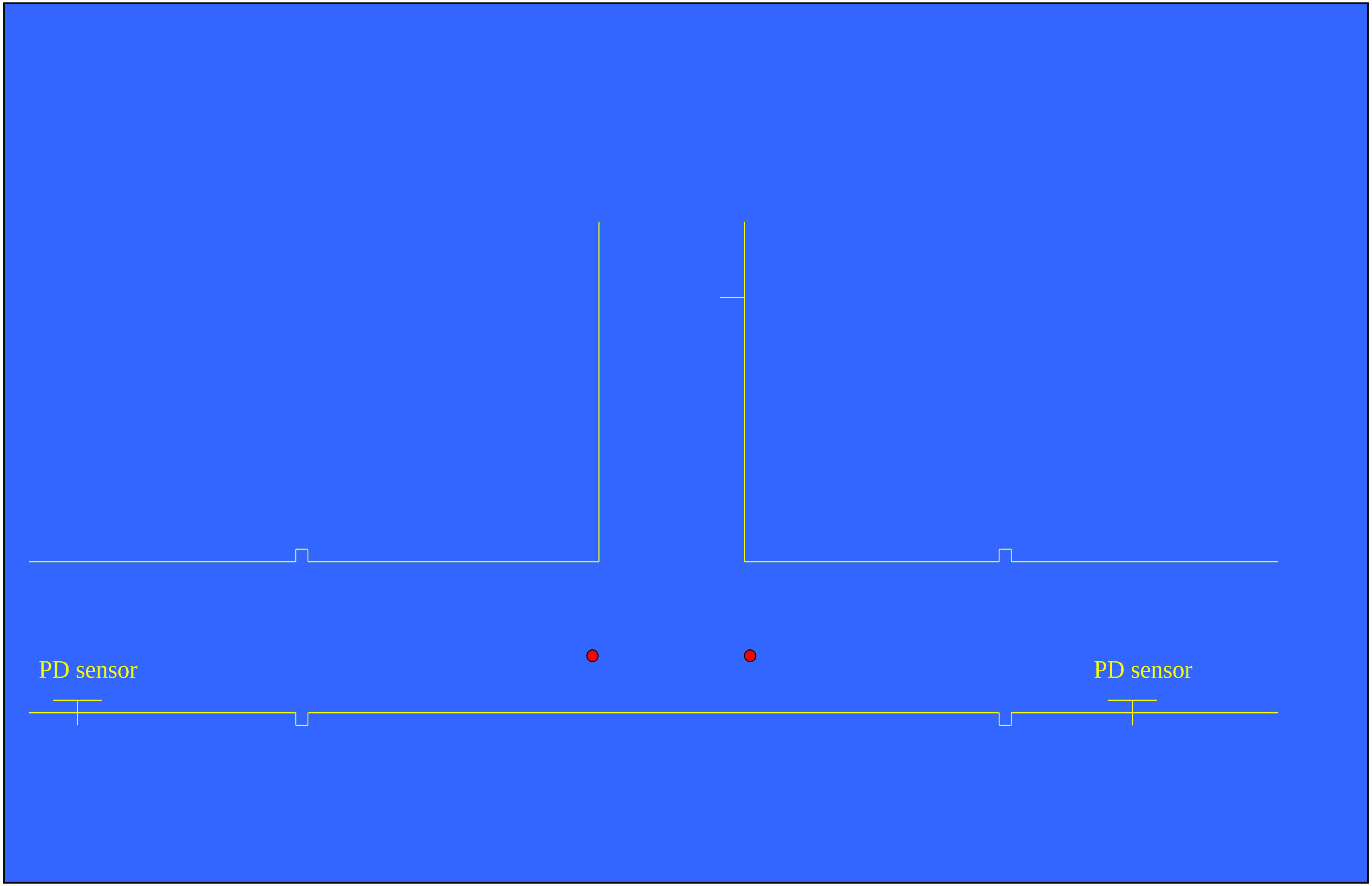
Conclusion

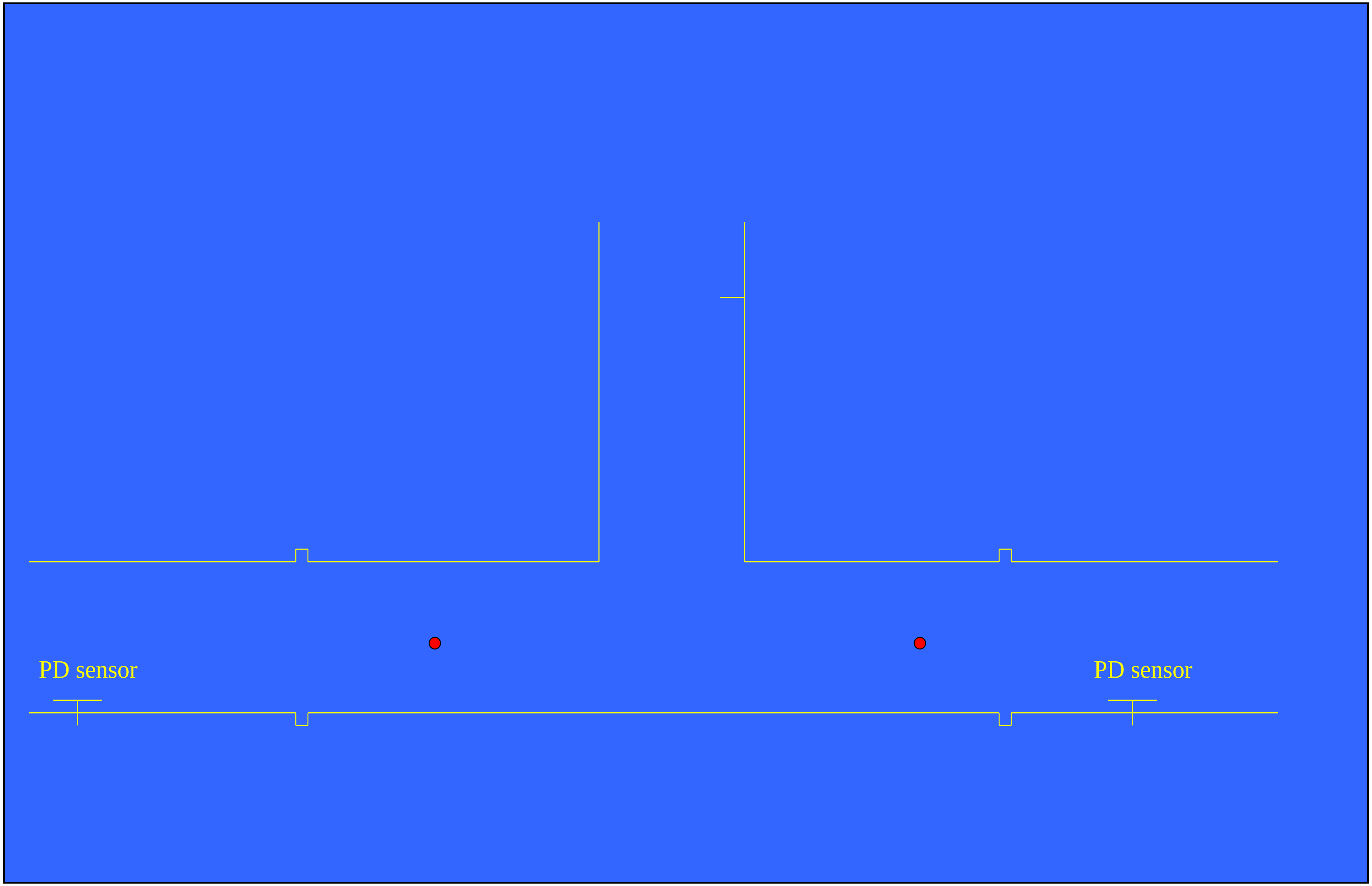
The result will always be at the coupler even if it is from outside of the two measurement points

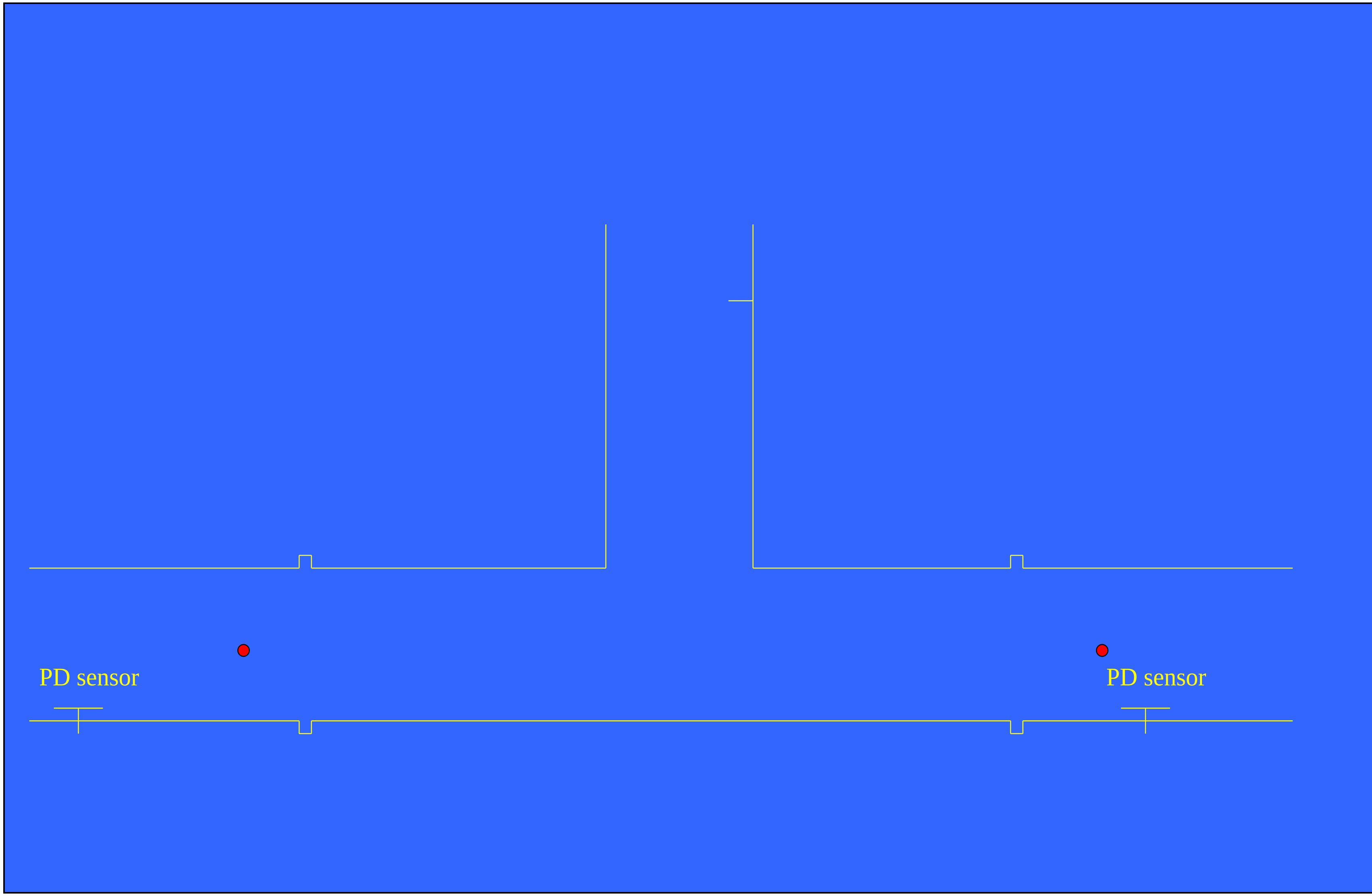
Defects from a T-junction

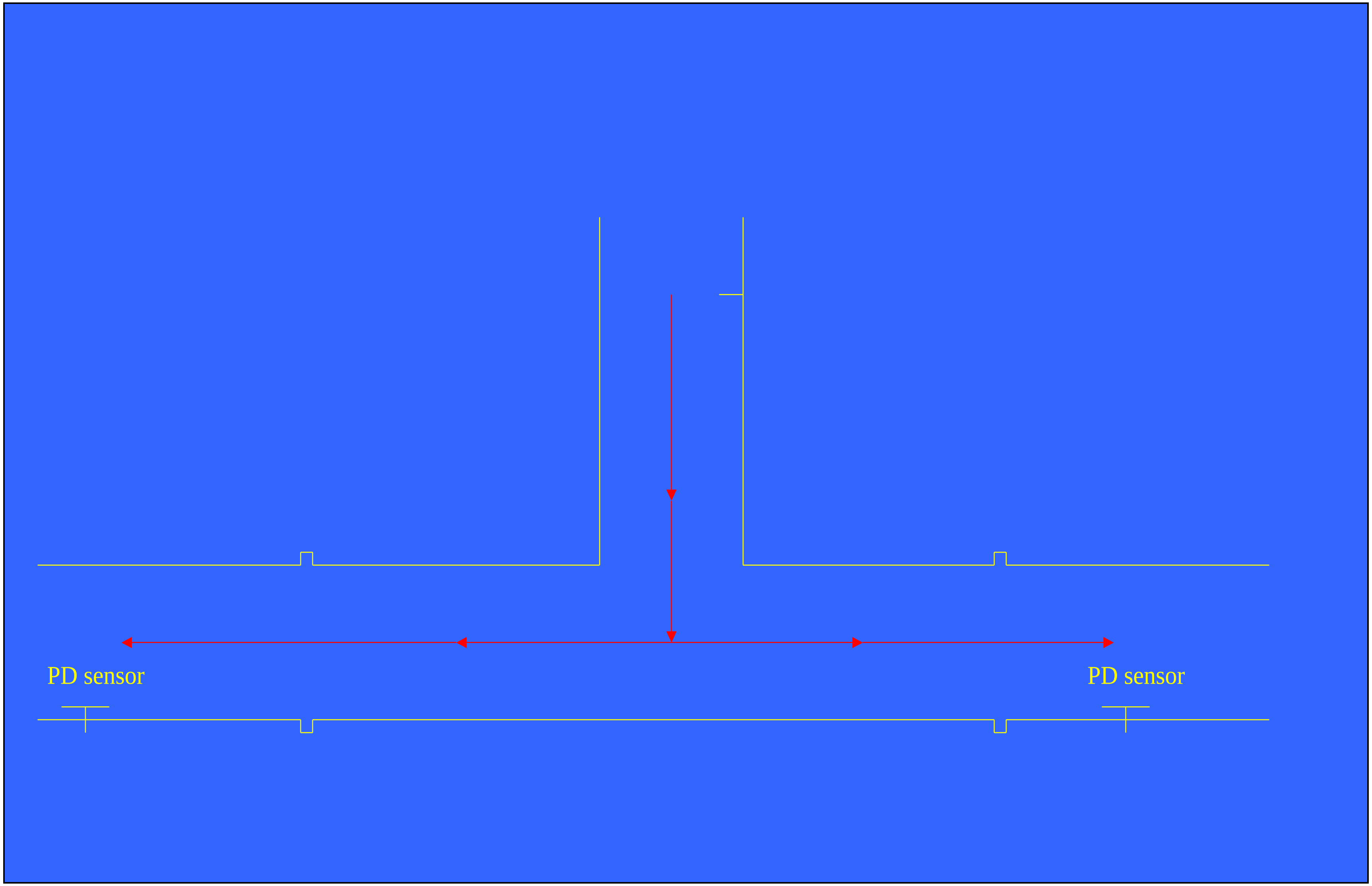

PD sensor
PD sensor


PD sensor
PD sensor


PD sensor
PD sensor


PD sensor
PD sensor


PD sensor
PD sensor

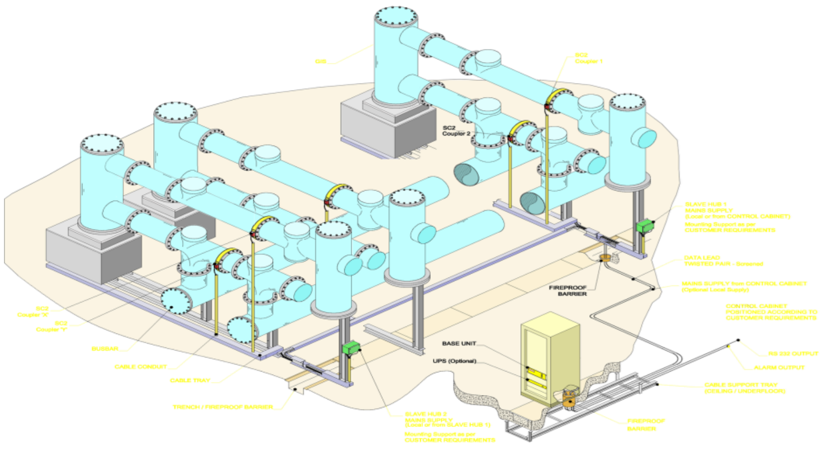

PD sensor
PD sensor

Conclusion

The result will always be at the T-junction regardless of how far along the T point the defect is


Questions?
AREVA

Continuous PD monitoring
For
Gas Insulated Switchgears GIS
(Fixed Unit)



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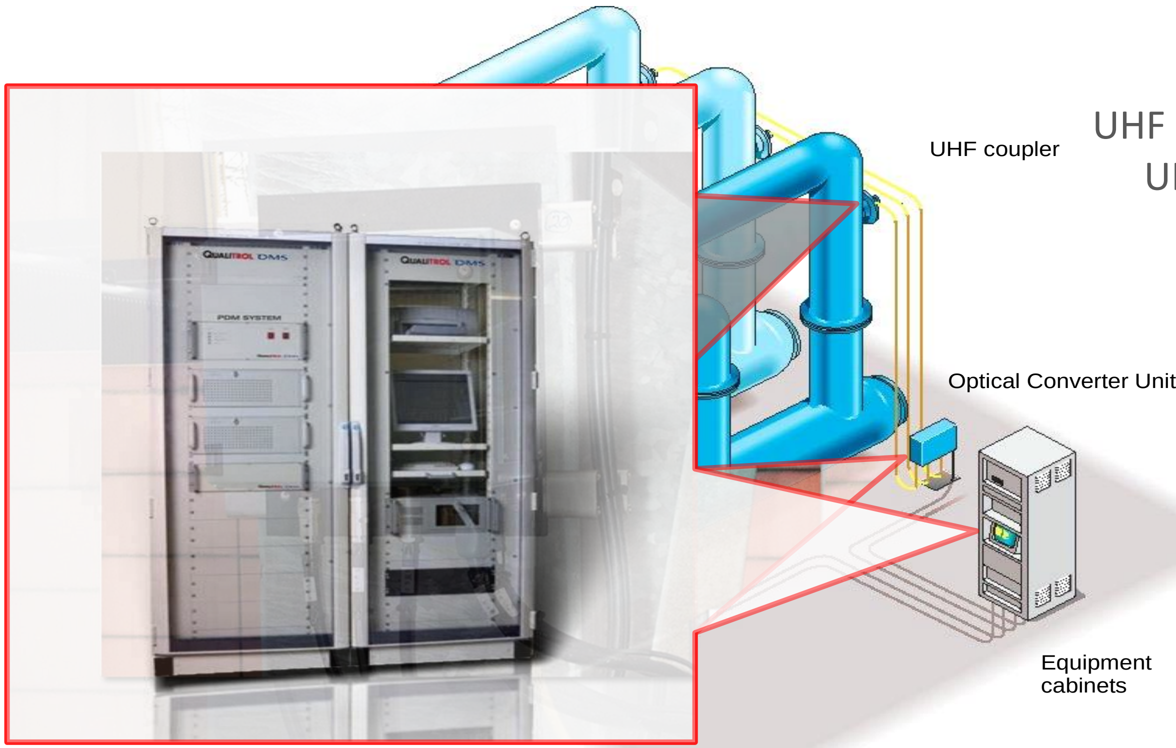
General Arrangement of PDM System



UHF Couplers – to take the UHF signals from the GIS.

OCU contains circuitry to detect and process the UHF signals from one three-phase set of couplers.

The UHF data is then transmitted via an optical fibre link

The central data handling, processing, storage and display are carried out within equipment cabinets located in the relay room

Continuous monitoring

ITAIPU GIS, Brazil

Continuous monitoring

Continuous monitoring

2 x 210 Sensor PDM systems in ITAIPU, Brazil

Reference List (1992-2010)

Year	Customer	Country	Couplers	Voltage, kV
2002	Itaipu	Brazil	12	500
2002	Itaipu	Paraguay	12	500
2002	KEPCO	Korea	27	345
2002	KEPCO	Korea	54	345
2002	KEPCO	Korea	51	345/154
2002	NGC	UK	138	400
2002	NGC	UK	27	400
2002	SCE	USA	33	220
2002	Senoko Power	Singapore	120	230
2002	Siemens	Germany	12	275-400
2003	SP PowerGrid	Singapore	93	230
2003	KEPCO	Korea	72	765
2003	KEPCO	Korea	69	765
2003	NGC	UK	12	400
2003	SEWA	Sharjah, UAE	114	400
2004	TNB	Malaysia	135	275/132
2004	Areva	Algeria	141	400
2004	CLP Power	Hong Kong	231	400
2004	DEWA	Dubai, UAE	120	400
2004	KEPCO	Korea	36	345
2004	KEPCO	Korea	48	345
2004	KEPCO	Korea	24	345
2004	KEPCO	Korea	48	345
2004	KEPCO	Korea	81	345
2004	NGC	UK	48	400
2004	SP PowerGrid	Singapore	87	230

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